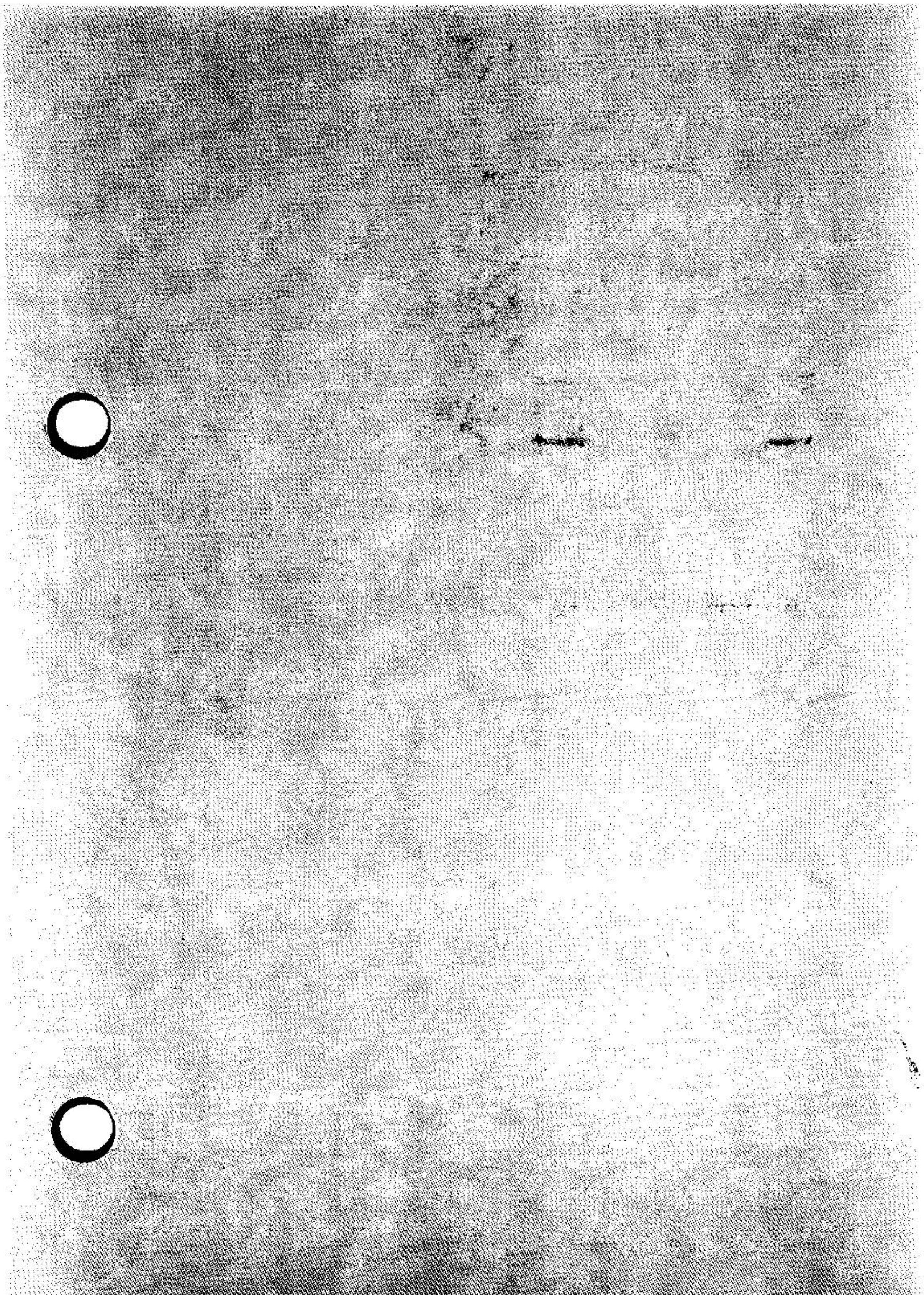
Methods for Estimating Monthly Streamflow Characteristics at Ungaged Sites in Western Montana



Prepared in cooperation with the U.S. Bureau of Indian Affairs and the Confederated Salish and Kootenai Tribes

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By CHARLES PARRETT and KENN D. CARTIER

Prepared in cooperation with the U.S. Bureau of Indian Affairs
and the Confederated Salish and Kootenai Tribes

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CONVERSION FACTORS

For readers who wish to convert measurements from the inch-pound system of units to the metric system of units, the conversion factors are listed below:

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.028317	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
inch (in.)	25.4	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)

ALTITUDE DATUM

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

Methods for Estimating Monthly Streamflow Characteristics at Ungaged Sites in Western Montana

By Charles Parrett[1] *and* Kenn D. Cartier[2]

Abstract

Three methods for estimating mean monthly discharge and various points on the daily mean flow-duration curve for each month (daily mean discharges that were exceeded 90, 70, 50, and 10 percent of the time each month) were developed for western Montana. A procedure for weighting two or more individual estimates to provide a minimum-variance weighted-average estimate also was developed. This report describes the estimation methods developed and their reliability and limitations.

The first method is based on multiple-regression equations relating the monthly streamflow characteristics to various basin and climatic variables. Standard errors of the basin-characteristics equations range from 43 to 107 percent. The basin-characteristics equations are generally not applicable to streams that receive or lose water as a result of localized geologic features or to stream sites that have appreciable upstream storage or diversions.

The second method is based on regression equations relating the monthly streamflow characteristics to channel width. Standard errors of the channel-width estimating equations range from 41 to 111 percent. The channel-width equations are generally not applicable to stream sites having exposed bedrock, braided or sand channels, or recent alterations.

The third method requires 12 once-monthly streamflow measurements at the ungaged site of interest. The 12 measured flows are then correlated with concurrent flows at some nearby gaged site by use of the curve-fitting technique MOVE.1 (Maintenance of Variance Extension, Type 1), and the relation defined is used to estimate the required monthly streamflow characteristic at the ungaged site from the streamflow characteristic at the gaged site. Standard errors, which are estimated by applying the method to 20 other gaged sites, range from 19 to 92 percent. Although generally substantially more reliable than either the basin-characteristics method or the channel-width method, this method may yield unreliable results if the measurement site and the correlating gaged site are not hydrologically similar.

The procedure for weighting individual estimates is based on the variance and degree of independence of the individual estimating methods. Standard errors for the weighted estimates of the monthly flow characteristics range from 15 to 43 percent when all three methods are used. The weighted-average estimates from all three methods are generally substantially more reliable than any of the individual estimates.

INTRODUCTION

Although western Montana generally has abundant surface water, shortages are common because of the large areal and seasonal variability of runoff. Making sound management decisions to relieve periodic shortages and to most efficiently allocate the supply among competing users thus requires reliable information about the variability of streamflow. In particular, the distribution of daily mean discharge by month is of interest to fish and wildlife managers, water-rights administrators, and other land- and water-use planners and managers. Unfortunately, techniques for estimating monthly streamflow characteristics are not as readily available as techniques for estimating annual and peak streamflow characteristics. For example, the only U.S. Geological Survey report containing estimating equations for mean monthly discharge in Montana is one by Boner and Buswell (1970); that report is based on a relatively small number of streamflow-gaging stations having at least 10 years of record then available. A more recent report by Parrett and Hull (1985, p. 8, 9) indicates that mean monthly discharge can be estimated at an ungaged site by using existing techniques to estimate a mean annual discharge and then assuming that the monthly distribution of the annual discharge follows the same distribution as some nearby gaged site. The accuracy of the estimated monthly mean discharge by use of this technique, however, is not completely satisfactory in western Montana.

Because of the dearth of techniques available for estimating monthly streamflow characteristics at ungaged sites in western Montana, the present study was undertaken in 1985 in cooperation with the U.S. Bureau of Indian

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[2] Confederated Salish and Kootenai Tribes.

Affairs and the Confederated Salish and Kootenai Tribes of the Flathead Indian Reservation. The objective of the project was to develop techniques for estimating long-term mean monthly discharge and various points on the daily mean flow-duration curve for each month (daily mean discharges that were exceeded 90, 70, 50, and 10 percent of the time each month) that would be applicable within the boundaries of the Flathead Indian Reservation in western Montana.

Purpose and Scope

The purpose of this report is to describe the estimation methods that were developed and to discuss their reliability and limitations. Three methods for estimating the required discharges were developed. One method is based on the relation between streamflow and various basin and climatic variables. The second method is similar to the first and is based on the relation between discharge and channel width. The third method requires once-monthly measurements of discharge at the ungaged site of interest and is based on the relation between the measured discharges and concurrent daily mean discharges at a similar, nearby gaged site. A procedure also is presented for weighting the individual estimates of discharge made from two or more of the three separate methods. The weighted-average estimate is based on the variance and degree of independence of the individual estimating methods. Calculated standard errors of prediction are used as a measure of reliability of each estimating method, and experience gained in the development and application of the methods is used to describe the major limitations.

Description of Study Area

Because of the small number of streamflow-gaging stations having monthly discharge data within the Flathead Indian Reservation, the study area was expanded to include the entire part of the State within the upper Columbia River basin as well as the adjacent eastern side of the Rocky Mountains (fig. 1). This area, termed "western Montana" for the purposes of this report, is composed largely of north- to northwest-trending mountain ranges separated by long, fairly narrow valleys. Except for the valley-floor areas, the study area is generally rugged and forested. The flatter valleys are mostly cultivated or grazed. The Flathead Indian Reservation, like the larger study area, is composed of both mountains and valleys. The reservation is bounded on the east by the rugged Mission Mountains and on the south and west by less rugged and less prominent mountains. Much of the interior part of the reservation includes broad intermontane valleys and gently rolling prairies.

Annual precipitation varies widely in the study area, primarily because of orographic effects. Annual precipitation tends to be greatest in the mountains, where it is as much as 100 in. in the northeastern corner of the study area and in the Mission Mountains on the eastern edge of the Flathead Indian Reservation (U.S. Soil Conservation Service, 1981, p. 1–2). In the drier valley areas, including the Little Bitterroot River valley within the Flathead Indian Reservation, annual precipitation is as little as 12 in.

Annual runoff generally follows the precipitation pattern, with greater quantities occurring in the areas of higher elevation. Streamflows vary greatly on a seasonal basis, as snowmelt provides the bulk of annual runoff in May, June, and July for the mountain streams and in March, April, and May for the streams draining the lower foothills and valley-floor areas. The smallest streamflows generally occur in late fall and winter when streamflows are almost entirely the result of ground-water inflow. Smaller streams draining the valleys may become dry during this period.

Streamflow Data Used

Monthly streamflow characteristics were computed from data at 59 streamflow-gaging stations within the study area, including 12 stations within the Flathead Indian Reservation. All stations used in the analysis had at least 5 years of record through water year 1986, although some stations did not have a complete record for all months. Streamflow-gaging stations where flows are substantially regulated or where large diversions substantially affect most flows were not used in the analyses. The locations of the streamflow-gaging stations used are shown in figure 1. The monthly streamflow characteristics computed for each station are listed in table 11 in the Supplemental Data section at the back of the report.

METHODS FOR ESTIMATING MONTHLY STREAMFLOW

Basin-Characteristics Method

One method for estimating streamflow characteristics at ungaged sites uses multiple-regression equations that relate streamflow characteristics at gaged sites to various measured basin and climatic variables. This method, termed the "basin-characteristics method" in this report, has commonly been used in Montana to estimate flood flows and mean annual flows (Parrett and Omang, 1981; Parrett and Hull, 1985; Omang and others, 1986).

Because the basin-characteristics method has been widely used, several basin and climatic variables have been measured previously at virtually every U.S. Geological Survey streamflow-gaging station in Montana. These measurement data are stored in the Basin Characteristics File of

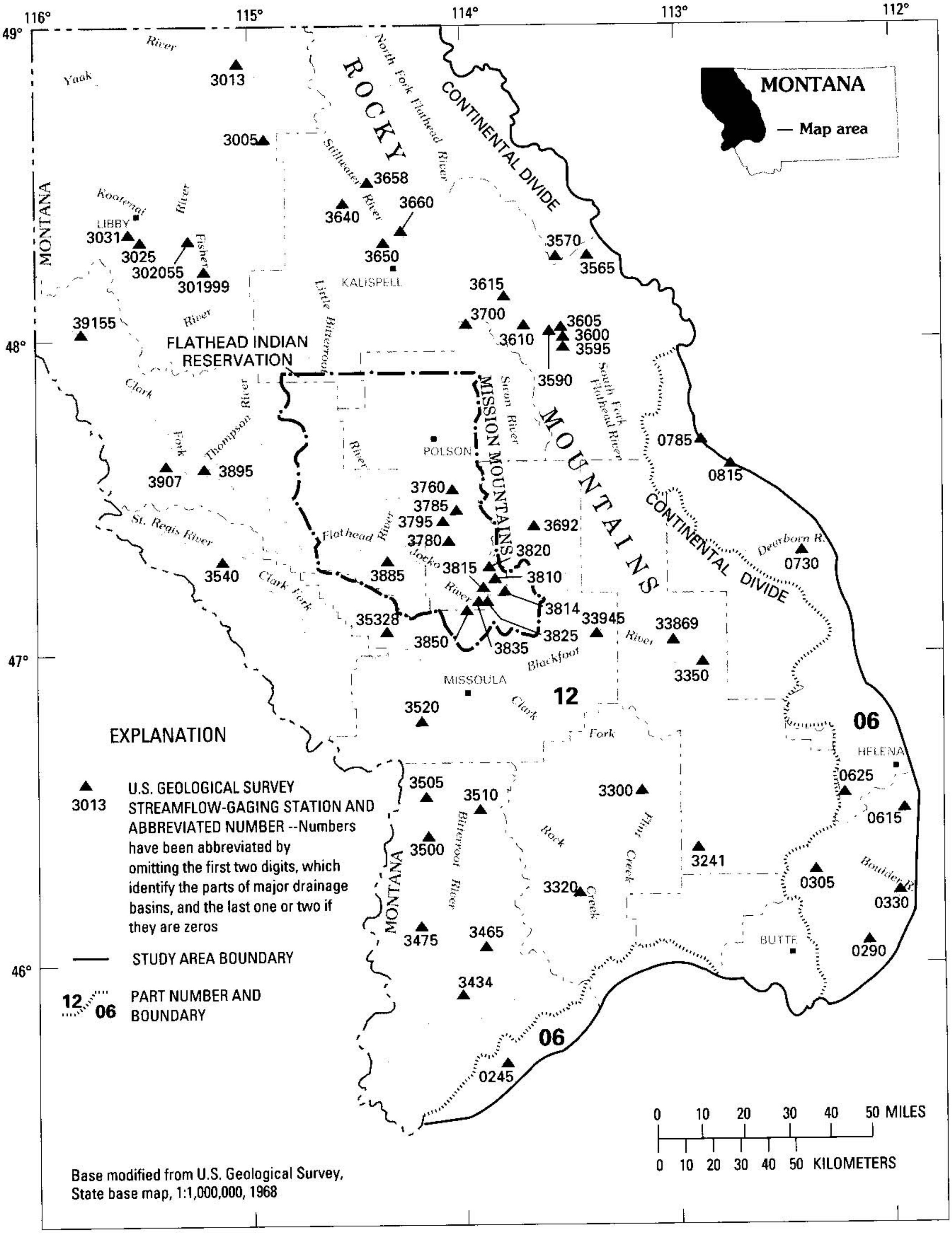

Figure 1. Location of streamflow-gaging stations.

the U.S. Geological Survey's Water Data Storage and Retrieval System (WATSTORE).

Boner and Buswell (1970) used basin characteristics to develop estimating equations for mean monthly flow in Montana, but the reported accuracy was generally unacceptable. According to Riggs (1972, p. 13–14), the basin-characteristics method is not well suited for the estimation of low flows, because low flows are largely affected by localized geology that cannot be quantified easily. For this study, several previously unmeasured basin characteristics that might be indicative of basin geology were investigated. Eighteen streamflow-gaging stations (table 1) in the study area were randomly selected, and the following geomorphic variables were measured at each site on U.S. Geological Survey topographic maps: basin perimeter, basin slope, circularity ratio, maximum basin relief, drainage density, stream frequency, and aspect.

Basin perimeter, expressed in miles, was determined by measuring the basin drainage area outline on the best-scale topographic map available. Basin slope, which is dimensionless, was determined by measuring the lengths of all contours at a fixed contour interval within the basin, multiplying by the contour interval, and dividing by the basin drainage area. Because the number of contours is largely dependent on the map scale, a single scale (1:24,000 U.S. Geological Survey 7.5-minute quadrangle maps) was used for determining basin slope at all sites; the contour interval selected was 400 ft. The map scale used at any ungaged site needs to be the same to ensure that the equations are applicable. Circularity ratio, which is also dimensionless, was determined by dividing the basin drainage area by the area of a circle having the same basin perimeter. Maximum basin relief, expressed in thousands of feet, was determined by subtracting the elevation of the stream at the basin outlet from the maximum elevation contour within the basin boundary shown on the contour map. Drainage density, expressed in miles per square mile, was determined by measuring and totaling the lengths of all channel segments shown on the contour map and dividing the result by the basin drainage area. As with basin slope, only 1:24,000 quadrangle maps were used to determine drainage density and the closely related variable, stream frequency. Stream frequency, expressed as a number per square mile, was determined by dividing the total number of stream segments by the basin drainage area. Aspect, expressed in degrees, was determined by measuring the angle from north to the line connecting the basin centroid to the basin outlet. Measurements of aspect were made either clockwise or counterclockwise from north so that the maximum possible aspect was 180°. Thus, a line from the centroid to the outlet oriented due west would result in an aspect of 90°, as would a line from the centroid to the outlet oriented due east.

The newly measured basin characteristics were combined with 10 standard basin and climatic characteristics previously measured at the 18 stations and treated as independent variables in a multiple-regression analysis. The 10 standard basin and climatic characteristics used were the following: drainage area, percentage of basin above 6,000 ft elevation, main-channel length, mean annual precipitation, mean basin elevation, main-channel slope, percentage of basin covered by forest, percentage of basin composed of lakes and ponds, precipitation intensity of a storm of 24 hours duration having a recurrence interval of 2 years, and mean January minimum temperature. Individual equations for five monthly flow characteristics for each month (60 equations) were developed by using a computerized stepwise regression procedure. On the basis of this initial analysis, the only new basin characteristics that were significant were basin perimeter, basin slope, circularity ratio, and maximum basin relief. Accordingly, these four new basin characteristics were considered to be worthy of inclusion in a regression analysis in which all available streamflow-gaging-station data in the study area were used, and they were subsequently measured at 54 gaged sites. Suitable topographic maps were not available for four gaged sites (stations 06030500, 06033000, 06061500, and

Table 1. Streamflow-gaging stations used to investigate new basin characteristics

Formal station no.	Abbreviated station no. (fig. 1)	Stream name
06062500	0625	Tenmile Creek
06078500	0785	North Fork Sun River
12300500	3005	Fortine Creek
12301999	301999	Wolf Creek
12302055	302055	Fisher River
12302500	3025	Granite Creek
12303100	3031	Flower Creek
12324100	3241	Racetrack Creek
12330000	3300	Boulder Creek
12338690	33869	Monture Creek
12343400	3434	East Fork Bitterroot River
12347500	3475	Blodgett Creek
12350500	3505	Kootenai Creek
12356500	3565	Bear Creek
12357000	3570	North Fork Flathead River
12359500	3595	Spotted Bear River
12361500	3615	Graves Creek
12364000	3640	Logan Creek

06081500), so these sites were excluded from the regression analysis. In addition, station 12359000 was excluded from the regression analysis because total streamflows at this site are substantially greater than at any other site used in the analysis.

In the multiple-regression analysis in which the 54 gaged sites were used, the following basin and climatic variables were significant in at least one regression equation:

- A drainage area,
- $E6$ percentage of basin above 6,000 ft elevation, plus 1,
- PE basin perimeter,
- BSL basin slope,
- L main-channel length,
- P mean annual precipitation,
- E mean basin elevation,
- BR maximum basin relief.

The most significant variable in almost all instances was main-channel length. Main-channel length is more susceptible to human change and measurement error than is drainage area, however, so drainage area was substituted for main-channel length and the regressions were repeated. Because main-channel length and drainage area are highly correlated, the substitution produced no substantial change in regression reliability. Although circularity ratio was determined to be significant in the initial regression analysis in which 18 test sites were used, it was not significant in the analysis in which all 54 gaged sites were used.

Drainage area, expressed in square miles, was determined by planimetering on the topographic map having the best scale. Percentage of basin above 6,000 ft elevation above sea level was determined by planimetering the drainage area above the 6,000-ft contour on the best topographic map available, dividing by the total drainage area, multiplying by 100, and adding 1 to ensure that 0 values did not occur. Mean annual precipitation, expressed in inches, was the basin average precipitation as determined from maps published by the U.S. Soil Conservation Service (1981). Mean basin elevation, expressed in thousands of feet, was determined by overlaying a transparent grid on the basin outline on a topographic map, reading the elevation at the grid intersections, and averaging the readings. The basin and climatic characteristics measured at each streamflow-gaging station used in the regression analysis are listed in table 12 at the back of the report.

Monthly streamflow data and basin and climatic characteristics at the 54 gaged sites in the study area were converted to logarithms and used in a multiple-regression analysis to derive estimating equations of the following linear form:

$$\log Q = \log a + b1 \log B + b2 \log C + \ldots bn \log N, \quad (1)$$

where

- Q (dependent variable) is the desired monthly streamflow characteristic in cubic feet per second (daily mean discharge that was exceeded 90, 70, 50, or 10 percent of the time during the given month, or mean discharge for the month);
- a is the multiple-regression constant;
- $b1, b2, \ldots bn$ are the regression coefficients; and
- $B, C, \ldots N$ are values of the significant basin characteristics (independent variables).

Taking antilogarithms yields the following nonlinear form of the regression equation:

$$Q = aB^{b1}\, C^{b2} \ldots N^{bn}. \quad (2)$$

The regressions were performed by using a computerized stepwise regression procedure that adds independent variables to the equation one at a time until all significant variables are included. In this study, a variable was included in the model if the F statistic was greater than 5. The computerized procedure also provided statistical measures of the applicability of the derived equations such as standard errors of estimate and coefficients of determination. In general, the smaller the standard error and the larger the coefficient of determination, the more reliable is the estimating equation.

To ensure that estimates from the regression equations for any month would be consistent, the initial equations for some streamflow characteristics were modified. In these instances, variables that were significant in most of the equations for any given month were selected as key variables, and the regressions were repeated by using the key variables as the only independent variables. For any given month, the equations for all streamflow characteristics thus have the same independent variables. Complete results of the regression analysis based on basin characteristics are given in table 2, along with the coefficients of determination and standard errors associated with each estimating equation.

As indicated by the results in table 2, the basin-characteristics equations generally are more reliable for estimating the higher flow monthly characteristics (for example, $Q.50$, $Q.10$, and QM) than the lower flow characteristics ($Q.90$ and $Q.70$) in any given month. The basin-characteristics equations also generally are more reliable for estimating flow characteristics for the months of high runoff (May and June) than for the months of generally low runoff (July through April).

Channel-Width Method

The second method used in this study for estimating monthly streamflow characteristics at ungaged sites also uses multiple-regression equations developed from gaged

Table 2. Results of regression analysis based on basin characteristics

[R^2, coefficient of determination; *Q.xx*, daily mean discharge exceeded *xx* percent of the time during the specified month, in cubic feet per second; *A*, drainage area, in square miles; *BR*, maximum basin relief, in thousands of feet; *BSL*, basin slope, dimensionless; *QM*, mean monthly discharge, in cubic feet per second; *P*, mean annual precipitation, in inches; *E*, mean basin elevation, in thousands of feet; *E6*, percentage of basin above 6,000 feet elevation, plus 1; *PE*, basin perimeter, in miles]

Month and number of sites	Streamflow characteristic	Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
October	$Q.90$	$= 0.123\ A^{0.84}\ BR^{1.31}\ BSL^{0.70}$	0.69	0.31	82
(50)	$Q.70$	$= 0.246\ A^{0.84}\ BR^{1.21}\ BSL^{0.92}$	.76	.26	66
	$Q.50$	$= 0.521\ A^{0.80}\ BR^{1.07}\ BSL^{1.06}$	.77	.24	60
	$Q.10$	$= 4.68\ A^{0.73}\ BR^{0.40}\ BSL^{1.19}$	.69	.25	63
	QM	$= 1.69\ A^{0.78}\ BR^{0.59}\ BSL^{1.16}$	.77	.22	54
November	$Q.90$	$= 0.140\ A^{0.89}\ BR^{1.21}\ BSL^{0.86}$	.76	.27	69
(49)	$Q.70$	$= 0.294\ A^{0.84}\ BR^{1.22}\ BSL^{1.05}$	.76	.25	63
	$Q.50$	$= 0.711\ A^{0.82}\ BR^{1.00}\ BSL^{1.28}$	.77	.24	60
	$Q.10$	$= 3.45\ A^{0.85}\ BR^{0.59}\ BSL^{1.74}$	.76	.24	60
	QM	$= 1.19\ A^{0.84}\ BR^{0.83}\ BSL^{1.48}$	.79	.23	57
December	$Q.90$	$= 0.132\ A^{0.92}\ BR^{1.18}\ BSL^{1.01}$	.76	.27	69
(49)	$Q.70$	$= 0.258\ A^{0.87}\ BR^{1.17}\ BSL^{1.11}$	.79	.24	60
	$Q.50$	$= 0.552\ A^{0.88}\ BR^{0.95}\ BSL^{1.33}$	.79	.24	60
	$Q.10$	$= 2.00\ A^{0.94}\ BR^{0.64}\ BSL^{1.76}$	.79	.25	63
	QM	$= 0.874\ A^{0.91}\ BR^{0.84}\ BSL^{1.57}$	.79	.24	60
January	$Q.90$	$= 0.117\ A^{0.96}\ BR^{1.23}\ BSL^{1.25}$	.77	.29	75
(47)	$Q.70$	$= 0.276\ A^{0.93}\ BR^{0.96}\ BSL^{1.26}$	.80	.24	60
	$Q.50$	$= 0.431\ A^{0.94}\ BR^{0.82}\ BSL^{1.27}$	.81	.24	60
	$Q.10$	$= 0.855\ A^{0.96}\ BR^{0.79}\ BSL^{1.36}$	.79	.25	63
	QM	$= 0.424\ A^{0.96}\ BR^{0.88}\ BSL^{1.30}$	.82	.24	60
February	$Q.90$	$= 0.176\ A^{0.98}\ BR^{0.99}\ BSL^{1.32}$	.81	.25	63
(47)	$Q.70$	$= 0.301\ A^{0.97}\ BR^{0.84}\ BSL^{1.28}$	.82	.23	57
	$Q.50$	$= 0.405\ A^{0.99}\ BR^{0.75}\ BSL^{1.35}$	.84	.22	54
	$Q.10$	$= 1.34\ A^{1.07}\ BR^{0.37}\ BSL^{1.66}$	.80	.26	66
	QM	$= 0.590\ A^{1.03}\ BR^{0.63}\ BSL^{1.53}$	.83	.23	57
March	$Q.90$	$= 0.174\ A^{0.99}\ BR^{1.03}\ BSL^{1.24}$	.82	.24	60
(48)	$Q.70$	$= 0.307\ A^{1.00}\ BR^{0.87}\ BSL^{1.31}$	.84	.23	57
	$Q.50$	$= 0.369\ A^{1.01}\ BR^{0.86}\ BSL^{1.32}$	.84	.23	57
	$Q.10$	$= 0.629\ A^{1.05}\ BR^{0.77}\ BSL^{1.23}$	.79	.27	69
	QM	$= 0.366\ A^{1.03}\ BR^{0.86}\ BSL^{1.22}$	.83	.24	60
April	$Q.90$	$= 0.0103\ A^{0.97}\ P^{1.43}\ E^{-0.86}$	.82	.23	57
(49)	$Q.70$	$= 0.0271\ A^{0.98}\ P^{1.50}\ E^{-1.29}$	.85	.22	54
	$Q.50$	$= 0.0758\ A^{0.96}\ P^{1.48}\ E^{-1.55}$	.83	.24	60
	$Q.10$	$= 0.119\ A^{1.01}\ P^{1.48}\ E^{-1.36}$	.80	.28	72
	QM	$= 0.0708\ A^{1.00}\ P^{1.46}\ E^{-1.38}$	.83	.25	63

Table 2. Results of regression analysis based on basin characteristics—Continued

Month and number of sites	Streamflow characteristic	Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
May	$Q.90$	$= 0.00100\ A^{1.00}\ P^{1.96}$	.80	.27	69
(52)	$Q.70$	$= 0.00321\ A^{1.04}\ P^{1.75}$	.83	.25	63
	$Q.50$	$= 0.00802\ A^{1.01}\ P^{1.64}$	.82	.24	60
	$Q.10$	$= 0.106\ A^{0.91}\ P^{1.25}$	.84	.21	51
	QM	$= 0.0249\ A^{0.96}\ P^{1.43}$	.84	.22	54
June	$Q.90$	$= 0.122\ A^{0.87}\ BSL^{1.06}\ P^{1.00}\ E6^{0.17}$	.77	.25	63
(53)	$Q.70$	$= 0.144\ A^{0.92}\ BSL^{0.98}\ P^{1.00}\ E6^{0.18}$	.85	.20	49
	$Q.50$	$= 0.245\ A^{0.91}\ BSL^{0.95}\ P^{0.95}\ E6^{0.19}$	.86	.19	46
	$Q.10$	$= 0.511\ A^{0.90}\ BSL^{0.79}\ P^{0.89}\ E6^{0.19}$	.87	.18	43
	QM	$= 0.284\ A^{0.90}\ BSL^{0.87}\ P^{0.92}\ E6^{0.19}$	.87	.18	43
July	$Q.90$	$= 0.192\ PE^{1.37}\ BR^{0.96}\ BSL^{1.31}$	.62	.33	88
(53)	$Q.70$	$= 0.173\ PE^{1.33}\ BR^{1.28}\ BSL^{1.06}$	.72	.27	69
	$Q.50$	$= 0.296\ PE^{1.33}\ BR^{1.18}\ BSL^{1.10}$	.75	.25	63
	$Q.10$	$= 0.871\ PE^{1.35}\ BR^{1.01}\ BSL^{1.20}$	.80	.21	51
	QM	$= 0.485\ PE^{1.33}\ BR^{1.03}\ BSL^{1.18}$	.78	.22	54
August	$Q.90$	$= 0.105\ PE^{1.43}\ BR^{0.65}\ BSL^{1.11}$	.57	.38	107
(53)	$Q.70$	$= 0.0931\ PE^{1.39}\ BR^{0.92}\ BSL^{0.90}$	.63	.34	92
	$Q.50$	$= 0.0978\ PE^{1.33}\ BR^{1.12}\ BSL^{0.75}$	.66	.31	82
	$Q.10$	$= 0.209\ PE^{1.26}\ BR^{1.07}\ BSL^{0.64}$	.72	.26	66
	QM	$= 0.136\ PE^{1.32}\ BR^{0.97}\ BSL^{0.77}$	.69	.28	72
September	$Q.90$	$= 0.0420\ PE^{1.46}\ BR^{0.90}\ BSL^{0.92}$	.60	.37	103
(53)	$Q.70$	$= 0.0522\ PE^{1.42}\ BR^{0.93}\ BSL^{0.72}$	.65	.33	88
	$Q.50$	$= 0.0604\ PE^{1.35}\ BR^{1.12}\ BSL^{0.67}$	.66	.30	78
	$Q.10$	$= 0.202\ PE^{1.24}\ BR^{0.98}\ BSL^{0.70}$	.74	.23	57
	QM	$= 0.102\ PE^{1.33}\ BR^{0.97}\ BSL^{0.78}$	.73	.25	63

data. In this instance, however, monthly streamflow characteristics at gaged sites are related to measured-channel widths at the gaged sites rather than to measured-basin characteristics. This method, termed the "channel-width method" in this report, has been used with generally good success in Montana and elsewhere for the estimation of flood flows and mean annual flows (Hedman and Osterkamp, 1982; Omang and others, 1983; Parrett and others, 1983; Cartier, 1984; Wahl, 1984). Because channel size is presumed to be largely the result of bankfull or near-bankfull flows, the channel-width method generally has not been used for monthly or low-flow characteristics. Nevertheless, the method was investigated for this study because the channel width had previously been measured at most of the gaged sites and because the relation between monthly flow characteristics and bankfull flows is fairly consistent for most perennial streams in the study area.

Channel features previously measured at gaged sites were active-channel width and bankfull width. At most sites the two features were about equally prominent and identifiable.

Osterkamp and Hedman (1977, p. 256) described the active channel as

> . . .a short-term geomorphic feature subject to change by prevailing discharges. The upper limit is defined by a break in the relatively steep bank slope of the active channel to a more gently sloping surface beyond the channel edge. The break in slope normally coincides with the lower limit of permanent vegetation so that the two features, individually or in combination, define the active channel reference level. The section

beneath the reference level is that portion of the stream entrenchment in which the channel is actively, if not totally, sculpted by the normal process of water and sediment discharge.

The bankfull-channel section (also referred to as the main-channel or whole-channel section) was described by Riggs (1974, p. 53) as "...variously defined by breaks in bank slope, by the edges of the flood plain, or by the lower limits of permanent vegetation." On perennial streams, the upper extent of the bankfull-channel section corresponds to the bankfull stage at a narrow stream section described by Leopold and others (1964). For most sites in the study area, the bankfull width was only slightly larger than the active-channel width. The lower limit of permanent vegetation was most commonly the recognizable reference feature for active-channel width, whereas the prominent break in slope was most commonly used to define bankfull width.

In this study, the monthly streamflow characteristics and measured-channel widths were converted to logarithms, and multiple-regression techniques were used to derive estimating equations relating monthly streamflow to either active-channel or bankfull width:

$$\log Q = \log a + b \log W, \qquad (3)$$

where

Q is a monthly streamflow characteristic as previously defined,

a is the regression constant,

b is the regression coefficient, and

W is the significant independent variable, either active-channel width (W_{AC}) or bankfull width (W_{BF}).

The nonlinear form of equation 3, obtained by taking antilogarithms, is the following:

$$Q = a\,W^{b}. \qquad (4)$$

The final regression equations derived by using channel widths and their coefficients of determination and standard errors are given in table 3. As with the basin-characteristics equations, the channel-width equations are generally more reliable for the higher flow characteristics ($Q.50$, $Q.10$, and QM) than for the lower flow characteristics ($Q.90$ and $Q.70$). Likewise, the channel-width equations are more reliable for the months of high runoff than for the months of low runoff and base flow. When measurement error is ignored, comparison of results in tables 2 and 3 indicates that the basin-characteristics equations and channel-width equations are about equally reliable for most flows for most months.

Concurrent-Measurement Method

The third method for estimating monthly streamflow characteristics at an ungaged site requires a series of

Table 3. Results of regression analysis based on channel width

[R^2, coefficient of determination; $Q.xx$, daily mean discharge exceeded xx percent of the time during the specified month, in cubic feet per second; W_{AC}, active-channel width, in feet; QM, mean monthly discharge, in cubic feet per second; W_{BF}, bankfull width, in feet]

Month and number of sites	Streamflow characteristic	Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
October	$Q.90$	$= 0.0521\ W_{AC}^{1.58}$	0.59	0.35	96
(44)	$Q.70$	$= 0.0774\ W_{AC}^{1.56}$	.67	.29	75
	$Q.50$	$= 0.116\ W_{AC}^{1.51}$	.72	.25	63
	$Q.10$	$= 0.383\ W_{AC}^{1.38}$	.73	.22	54
	QM	$= 0.186\ W_{AC}^{1.44}$	.78	.20	49
November	$Q.90$	$= 0.0508\ W_{AC}^{1.60}$	.66	.30	78
(43)	$Q.70$	$= 0.0875\ W_{AC}^{1.55}$	.69	.27	69
	$Q.50$	$= 0.124\ W_{AC}^{1.52}$	.74	.24	60
	$Q.10$	$= 0.215\ W_{AC}^{1.55}$	.78	.21	51
	QM	$= 0.138\ W_{AC}^{1.53}$	.77	.22	54
December	$Q.90$	$= 0.0356\ W_{AC}^{1.66}$	.67	.31	82
(43)	$Q.70$	$= 0.0695\ W_{AC}^{1.58}$	.71	.26	66
	$Q.50$	$= 0.0896\ W_{AC}^{1.57}$	.74	.25	63
	$Q.10$	$= 0.118\ W_{AC}^{1.68}$	.79	.23	57
	QM	$= 0.0875\ W_{AC}^{1.63}$	.76	.24	60

Table 3. Results of regression analysis based on channel width—Continued

Month and number of sites	Streamflow characteristic	Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
January	$Q.90$	$= 0.0270\ W_{AC}^{1.71}$	.69	.31	82
(41)	$Q.70$	$= 0.0398\ W_{AC}^{1.69}$	.75	.26	66
	$Q.50$	$= 0.0557\ W_{AC}^{1.66}$	.76	.24	60
	$Q.10$	$= 0.0735\ W_{AC}^{1.76}$	.80	.23	57
	QM	$= 0.0509\ W_{AC}^{1.73}$	.78	.24	60
February	$Q.90$	$= 0.0265\ W_{AC}^{1.73}$	.71	.29	75
(41)	$Q.70$	$= 0.0389\ W_{AC}^{1.71}$	.75	.26	66
	$Q.50$	$= 0.0444\ W_{AC}^{1.72}$	.77	.25	63
	$Q.10$	$= 0.0659\ W_{AC}^{1.80}$	.77	.26	66
	QM	$= 0.0476\ W_{AC}^{1.75}$	.77	.26	66
March	$Q.90$	$= 0.0320\ W_{AC}^{1.74}$	.74	.27	69
(42)	$Q.70$	$= 0.0416\ W_{AC}^{1.74}$	.75	.26	66
	$Q.50$	$= 0.0529\ W_{AC}^{1.74}$	.75	.26	66
	$Q.10$	$= 0.0633\ W_{AC}^{1.85}$	.75	.28	72
	QM	$= 0.0519\ W_{AC}^{1.79}$	.75	.27	69
April	$Q.90$	$= 0.0535\ W_{AC}^{1.75}$	.76	.26	66
(43)	$Q.70$	$= 0.0695\ W_{AC}^{1.82}$	.79	.25	63
	$Q.50$	$= 0.115\ W_{AC}^{1.81}$	.76	.27	69
	$Q.10$	$= 0.271\ W_{AC}^{1.85}$	.76	.27	69
	QM	$= 0.144\ W_{AC}^{1.83}$	.77	.25	63
May	$Q.90$	$= 0.0548\ W_{BF}^{1.95}$	.80	.25	63
(46)	$Q.70$	$= 0.0698\ W_{BF}^{2.03}$	.86	.21	51
	$Q.50$	$= 0.128\ W_{BF}^{1.96}$	.86	.20	49
	$Q.10$	$= 0.392\ W_{BF}^{1.85}$	.88	.18	43
	QM	$= 0.175\ W_{BF}^{1.91}$	.87	.19	46
June	$Q.90$	$= 0.265\ W_{BF}^{1.58}$	.68	.27	69
(47)	$Q.70$	$= 0.300\ W_{BF}^{1.67}$	.78	.22	55
	$Q.50$	$= 0.423\ W_{BF}^{1.67}$	.81	.21	50
	$Q.10$	$= 0.657\ W_{BF}^{1.72}$	.86	.17	41
	QM	$= 0.445\ W_{BF}^{1.68}$	.84	.19	46
July	$Q.90$	$= 0.162\ W_{AC}^{1.51}$	.58	.34	92
(47)	$Q.70$	$= 0.258\ W_{AC}^{1.51}$	.67	.29	75
	$Q.50$	$= 0.372\ W_{AC}^{1.51}$	.72	.25	63
	$Q.10$	$= 0.857\ W_{AC}^{1.51}$	.80	.20	49
	QM	$= 0.498\ W_{AC}^{1.49}$	.77	.22	54
August	$Q.90$	$= 0.0746\ W_{AC}^{1.54}$	.55	.37	103
(47)	$Q.70$	$= 0.107\ W_{AC}^{1.54}$	.59	.34	92
	$Q.50$	$= 0.163\ W_{AC}^{1.49}$	.60	.33	88
	$Q.10$	$= 0.347\ W_{AC}^{1.44}$	.68	.26	66
	QM	$= 0.191\ W_{AC}^{1.47}$	.65	.29	75

Table 3. Results of regression analysis based on channel width—Continued

Month and number of sites	Streamflow characteristic	Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
September	$Q.90$	$= 0.0545\ W_{AC}^{1.57}$	.54	.39	111
(47)	$Q.70$	$= 0.0741\ W_{AC}^{1.56}$	.60	.34	92
	$Q.50$	$= 0.112\ W_{AC}^{1.51}$	.62	.32	85
	$Q.10$	$= 0.278\ W_{AC}^{1.42}$	.72	.24	60
	QM	$= 0.142\ W_{AC}^{1.48}$	.69	.27	69

discharge measurements at the site. The measured discharges at the ungaged site are correlated with concurrent discharges at some nearby, hydrologically similar gaged site, and the relation between the discharges at the two sites is used to transfer the desired long-term streamflow characteristic at the gaged site to the ungaged site. This estimation method, referred to in this report as the "concurrent-measurement method," has been used previously in Montana to estimate mean annual streamflow (Parrett, 1985; Parrett and Hull, 1985) and selected flows on a duration curve of monthly mean streamflow (Parrett and Hull, 1986). According to Searcy (1959, p. 17) and Riggs (1972, p. 15), the concurrent-measurement method generally provides more reliable estimates of low-flow characteristics than other methods in which discharge measurements are not used.

The concurrent-measurement method investigated in this study requires 12 measurements (1 per month) at the ungaged site of interest. The measurements are paired with concurrent daily mean discharges obtained from a similar, nearby gaged site, and a straight line is plotted through the logarithms of the data points. The curve-fitting technique used (MOVE.1) is described by Hirsch (1982). The MOVE.1 technique is similar to an ordinary least-squares regression, except that ordinary regression minimizes the squared vertical deviations of the dependent variable from the regression line, whereas the MOVE.1 technique minimizes the areas of the right triangles formed by the horizontal and vertical deviations from the regression line (Hirsch and Gilroy, 1984, p. 707). The equation describing the ordinary least-squares regression line is the following:

$$y = \bar{y} + r\,(S_y/S_x)\,(x - \bar{x}), \tag{5}$$

where

y is the dependent variable,
$\bar{y}$ is the sample mean of the dependent variable,
r is the sample correlation coefficient between the dependent and independent variables,
S_y is the sample variance of the dependent variable,
S_x is the sample variance of the independent variable,
x is the independent variable, and
$\bar{x}$ is the sample mean of the independent variable.

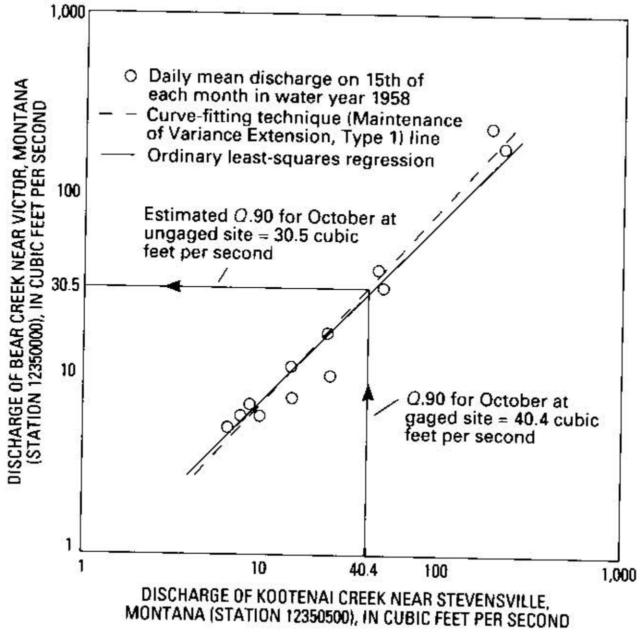

Figure 2. Comparison between lines for the curve-fitting technique and ordinary least-squares regression. Q.90, daily mean discharge exceeded 90 percent of the time during the specified month.

The following equation describing the MOVE.1 best-fit line is identical to equation 5 except that r is not included:

$$y = \bar{y} + (S_y/S_x)\,(x - \bar{x}), \tag{6}$$

where all terms are as defined above. An example of an ordinary regression line and a MOVE.1 line fit to concurrent daily mean discharges at two gaged sites is shown in figure 2. Although the two best-fit lines in figure 2 are similar, Stedinger and Thomas (1985) have shown that the MOVE.1 line is an unbiased estimator of low flows, whereas the ordinary regression line is a biased estimator of low flows. An alternative approach to the MOVE.1 or ordinary least-squares regression would be a visual fit to the 12 data points. Although a visual fit would be subjective, it would allow the fitting of curves or multiple straight-line segments rather than a simple straight line.

To obtain an estimate of a particular monthly flow characteristic at the ungaged site, the value of the flow characteristic at the gaged site is located along the horizontal axis and projected to the MOVE.1 line. The horizontal projection from the MOVE.1 line to the vertical axis yields the estimate at the ungaged site as shown in figure 2. As indicated by Searcy (1959, p. 20), the relation between concurrent high flows may be different from the relation between concurrent base flows so that a single straight line may not provide a good fit to the data. Riggs (1969) also showed that a difference in timing of runoff at two sites will result in a concurrent discharge plot that resembles a loop. Nevertheless, an examination of concurrent discharges from pairs of streamflow-gaging stations within the study area indicated that, in most instances, either the deviation from a single straight-line fit was not significant or the scatter about the line was great enough to mask any deviations. Accordingly, the reliability tests of the concurrent-measurement method are all based on a single MOVE.1 fit to the concurrent-measurement data. In applying the method at any particular site, however, the reader needs to be aware that a single straight line may not fit the data as well as two straight-line segments or that a timing-effects loop may exist. Using more complicated curve-fitting procedures in those instances will probably yield more accurate estimates than using the single MOVE.1 line.

To estimate the standard error of estimate of the concurrent-discharge method, the 20 pairs of streamflow-gaging stations listed in table 4 were tested. One station of each pair was selected to be the test site (herein called the pseudo-ungaged site) for which estimates of monthly streamflow were required, and the other station served as the nearby, hydrologically similar index site. The stations were chosen such that the degree of similarity between the pseudo-ungaged and gaged sites was about the same as would be expected in actual practice. Thus, in some instances both sites were located in adjacent drainages and were very similar, and in other instances the sites were many miles apart and probably not so similar. One year from the concurrent period of record at each pair of stations was randomly selected, and the recorded daily mean discharge on the 15th of each month was used as the measured discharge at the pseudo-ungaged site and as the concurrent discharge at the gaged site. The MOVE.1 technique was then used to fit a line to the 12 data points, and the fitted line was used to estimate the monthly flow characteristics at the pseudo-ungaged site from the known monthly flow characteristics at the gaged site as described above.

The standard deviation of the differences (residuals) between the actual monthly flow characteristics at the 20 pseudo-ungaged sites and the estimated monthly flow characteristics from the MOVE.1 line was considered to be analogous to the standard error of estimate computed for the basin-characteristics method and the channel-width method. The resultant calculated "standard errors" for the monthly

Table 4. Streamflow-gaging stations used in the test of the curve-fitting technique[1]

Station used as pseudo-ungaged site	Station used as index gaged site	Year of record used in test
06024500	06061500	1951
06030500	06033000	1947
06062500	06061500	1969
06073000	06078500	1951
06081500	06061500	1912
12301300	12302055	1980
12301999	12302055	1970
12303100	12302500	1968
12324100	12330000	1966
12346500	12343400	1967
12350000	12350500	1958
12351000	12350500	1958
12356500	12359000	1952
12360000	12359500	1953
12360500	12359500	1956
12361000	12359500	1956
12361500	12359500	1956
12365800	12366000	1979
12369200	12370000	1976
12390700	12389500	1983

[1]Maintenance of Variance Extension, Type 1 (MOVE.1).

flow characteristics as determined from the 20 pairs of stations are presumed to be a reasonable approximation of the expected reliability of the concurrent-measurement method and are listed in table 5. Comparison of the standard errors in table 5 with the standard errors for the basin-characteristics method in table 2 and with the standard errors for the channel-width method in table 3 indicates that the concurrent-measurement method is substantially more reliable than the other methods for all months and nearly all monthly flow characteristics.

Using the concurrent-measurement method with 12 once-monthly measurements requires a large investment of time and money. Therefore, it is of some interest to investigate whether a program of fewer measurements might provide estimates of acceptable accuracy. Accord-

Table 5. Standard errors for concurrent-measurement method based on 12 measurements

[*Q.xx*, daily mean discharge exceeded *xx* percent of the time during the specified month, in cubic feet per second; *QM*, mean monthly discharge, in cubic feet per second]

Month	Standard error, in percent, for specified monthly flow characteristic				
	Q.90	Q.70	Q.50	Q.10	QM
October	69	38	31	36	26
November	46	28	21	31	21
December	41	21	19	31	26
January	38	21	21	28	26
February	28	21	21	33	26
March	26	23	26	38	28
April	33	38	36	38	41
May	51	43	43	41	38
June	66	46	38	46	38
July	85	51	43	49	43
August	92	66	54	38	46
September	85	54	46	33	33

Table 6. Standard errors for concurrent-measurement method based on five measurements

[*Q.xx*, daily mean discharge exceeded *xx* percent of the time during the specified month, in cubic feet per second; *QM*, mean monthly discharge, in cubic feet per second]

Month	Standard error, in percent, for specified monthly flow characteristic				
	Q.90	Q.70	Q.50	Q.10	QM
October	82	49	38	75	49
November[1]	57	36	36	60	38
December[1]	43	28	28	60	36
January[1]	36	26	31	51	31
February[1]	31	23	26	46	31
March[1]	28	28	31	54	33
April	38	54	103	258	149
May	179	326	471	772	471
June	214	353	415	737	451
July	120	129	160	339	214
August	99	92	96	116	92
September	92	69	63	69	60

[1]Months when measurements were made.

ingly, the concurrent-measurement method was tested for the situation where only five once-monthly discharge measurements were available. For the same randomly selected year of record used in the 12-measurement test, the mid-monthly recorded discharge for the base-flow months November through March were used as data points for the 20 gage pairs, and the test described above was repeated. The five base-flow months were chosen for testing because many ungaged sites on the Flathead Indian Reservation had discharge measurements available for only those months. The computed standard errors for the concurrent-measurement method based on the five base-flow measurements are given in table 6. In this instance, the computed standard errors are substantially larger than the computed standard errors for the 12-measurement situation for most months when flow measurements were not available. The computed standard errors for the five-measurement situation are particularly large, substantially larger even than the standard errors for the basin-characteristics method or the channel-width method, April through July. Thus, the concurrent-measurement method based on fewer than 12 measurements may provide monthly flow estimates with an acceptable accuracy only for those months when measurements were made.

Weighted-Average Estimate

When different methods are available for estimating streamflow characteristics, it seems reasonable to assume that a weighted average of the individual estimates might provide a better answer than any of the individual estimates. When the individual estimates are independent, E.J. Gilroy (as cited by the U.S. Water Resources Council, 1981, p. 8–1) showed that the individual estimates could be weighted inversely proportional to their variances, and the resultant weighted average would have a smaller variance than any of the individual estimates.

To test whether the three estimating methods yield independent estimates, the cross-correlation coefficient between the residuals from the different methods was computed for 18 of the gaged sites used as pseudo-ungaged sites (table 4) in the concurrent-measurement method test. Two sites used in the concurrent-measurement test (stations 06030500 and 06081500) could not be used in this test because not all required basin-characteristics data were available. The equation used to compute the cross-correlation coefficient is the following:

$$r_{xy} = \frac{\sum_{i=1}^{N} x_i y_i - N\bar{x}\bar{y}}{(N-1)\,S_x S_y}, \qquad (7)$$

where

r_{xy} is the correlation coefficient between the residuals from method x and method y (ranges from -1.0 to 1.0),

N is the total number of sample residuals (18 in this computation),

x_i and y_i are the ith residuals from methods x and y,

$\bar{x}$ and $\bar{y}$ are the mean values of the residuals from methods x and y, and

S_x and S_y are the standard deviations of the residuals from methods x and y.

If the computed correlation coefficients between the residuals from any two estimating methods are zero or near zero, the two methods may be considered to be independent. The results of the correlation-coefficient computations for all methods are listed in tables 7–9.

As indicated by the results in table 7, the basin-characteristics method and the channel-width method yield monthly flow estimates that generally are not independent from each other. The results in tables 8 and 9 indicate that the concurrent-measurement method provides monthly flow estimates that are independent from either of the other two methods for some monthly flow characteristics for some months. For other flow characteristics and months, however, the concurrent-measurement method estimates are not independent from estimates made from the other two methods. Results in tables 8 and 9 also indicate that the correlation between the concurrent-measurement method and the other two methods commonly is negative. The negative correlations are an indication that the two methods being compared are providing estimates on either side of the true value and that the errors of the individual estimates might be compensating when the estimates are combined.

If the individual estimates are not independent, the following equations (E.J. Gilroy, U.S. Geological Survey, written commun., 1987) can be used to weight the individual estimates so as to yield the weighted-average estimate with the smallest variance:

$$Z = a1 \cdot x1 + a2 \cdot x2 + a3 \cdot x3, \tag{8}$$

where

Z is the unbiased, weighted estimate of some flow characteristic,

$a1$, $a2$, and $a3$ are weights that result in a minimum-variance, unbiased, linear combination of $x1$, $x2$, and $x3$, and

$x1$, $x2$, and $x3$ are estimates of the flow characteristic from three different methods.

Equations for the weights are as follows:

$$a1 = [C\,(SE_3^{\,2} - S_{1,3}) - B\,(SE_3^{\,2} - S_{2,3})]/(A\,C - B^2), \tag{9}$$

$$a2 = [A\,(SE_3^{\,2} - S_{2,3}) - B\,(SE_3^{\,2} - S_{1,3})]/(A\,C - B^2), \tag{10}$$

$$a3 = 1 - a1 - a2, \tag{11}$$

where

$C = SE_2^{\,2} + SE_3^{\,2} - 2\,S_{2,3}$,

SE_1, SE_2, and SE_3 are the standard errors of the three different estimating methods,

$S_{1,2} = r_{1,2}\,(SE_1 \cdot SE_2)$ and is the covariance of methods 1 and 2,

$S_{1,3} = r_{1,3}\,(SE_1 \cdot SE_3)$ and is the covariance of methods 1 and 3,

$S_{2,3} = r_{2,3}\,(SE_2 \cdot SE_3)$ and is the covariance of methods 2 and 3,

$r_{i,j}$ is the cross-correlation coefficient between estimates from methods i and j,

$A = SE_1^{\,2} + SE_3^{\,2} - 2\,S_{1,3}$, and

$B = SE_3^{\,2} + S_{1,2} - S_{1,3} - S_{2,3}$.

The estimated standard error of the weighted estimate, SE_z, is determined as follows:

$$SE_z = [(a1 \cdot SE_1)^2 + (a2 \cdot SE_2)^2 + (1 - a1 - a2)^2\,SE_3^{\,2} + 2\,a1 \cdot a2 \cdot S_{1,2} + 2\,a1\,(1 - a1 - a2)\,S_{1,3} + 2\,a2\,(1 - a1 - a2)\,S_{2,3}]^{0.5}, \tag{12}$$

where all terms are as previously defined.

If only two of the estimating methods are used, the following equations for computing weights and standard error are applicable:

$$Z = a1 \cdot x1 + a2 \cdot x2, \text{ and} \tag{13}$$

$$SE_z = \sqrt{SE_1^{\,2}\,SE_2^{\,2} - S_{1,2}^{\,2})/(SE_1^{\,2} + SE_2^{\,2} - 2\,S_{1,2})} \tag{14}$$

where

$a1 = (SE_2^{\,2} - S_{1,2})/(SE_1^{\,2} + SE_2^{\,2} - 2\,S_{1,2})$, and

$a2 = (SE_1^{\,2} - S_{1,2})/(SE_1^{\,2} + SE_2^{\,2} - 2\,S_{1,2})$.

The above equations were used to calculate weights and standard errors for all combinations of the three estimating methods. For the basin-characteristics method and the channel-width method, the standard errors are based on the regression data from 54 gaged sites. The standard errors for the concurrent-measurement method are based on data from 20 gaged sites (table 4). The results, listed in table 13 at the back of the report, indicate that considerably more weight is given to the concurrent-measurement method estimates than to either the basin-characteristics method or channel-width method estimates for all monthly streamflow characteristics for all months. Likewise, the weighted standard errors are substantially less when the concurrent-measurement estimates are included in the weighting procedure than when only estimates from the basin-characteristics method and channel-width method are used.

Table 7. Correlation between residuals from basin-characteristics method and channel-width method

[*Q.xx*, daily mean discharge exceeded *xx* percent of the time during the specified month, in cubic feet per second; *QM*, mean monthly discharge, in cubic feet per second]

Flow characteristic	Correlation coefficient between residuals for specified month											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Q.90	0.73	0.63	0.63	0.60	0.57	0.50	0.35	0.36	0.62	0.79	0.85	0.84
Q.70	.63	.58	.54	.52	.51	.46	.10	.18	.40	.68	.80	.79
Q.50	.57	.52	.51	.49	.43	.45	.18	.18	.31	.60	.77	.76
Q.10	.68	.45	.41	.42	.49	.52	.30	.19	.16	.45	.68	.65
QM	.54	.44	.45	.43	.45	.46	.17	.17	.23	.52	.74	.69

Table 8. Correlation between residuals from basin-characteristics method and concurrent-measurement method

[*Q.xx*, daily mean discharge exceeded *xx* percent of the time during the specified month, in cubic feet per second; *QM*, mean monthly discharge, in cubic feet per second]

Flow characteristic	Correlation coefficient between residuals for specified month											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Q.90	-0.34	-0.22	-0.11	-0.17	-0.16	-0.05	-0.18	-0.52	-0.46	-0.49	-0.42	-0.44
Q.70	-.47	-.56	-.27	.02	-.08	-.15	-.38	-.41	-.29	-.42	-.42	-.44
Q.50	-.53	-.51	-.34	.01	-.03	-.12	-.36	-.33	-.24	-.32	-.38	-.44
Q.10	-.46	-.47	-.34	-.21	-.37	-.26	-.56	-.09	.03	-.05	-.22	-.30
QM	-.18	-.34	-.20	.19	-.09	-.09	-.36	-.20	-.16	-.06	-.24	-.28

Table 9. Correlation between residuals from channel-width method and concurrent-measurement method

[*Q.xx*, daily mean discharge exceeded *xx* percent of the time during the specified month, in cubic feet per second; *QM*, mean monthly discharge, in cubic feet per second]

Flow characteristic	Correlation coefficient between residuals for specified month											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Q.90	-0.45	-0.30	-0.21	-0.19	-0.05	0.18	-0.12	-0.42	-0.50	-0.47	-0.47	-0.51
Q.70	-.48	-.37	-.09	-.01	-.06	-.13	-.10	-.39	-.52	-.49	-.54	-.59
Q.50	-.43	-.19	-.03	.10	-.07	-.03	-.11	-.38	-.53	-.50	-.58	-.63
Q.10	-.46	-.44	-.26	.01	-.02	.08	-.23	-.17	-.23	-.57	-.65	-.55
QM	-.05	-.02	-.05	.34	.06	.11	-.03	-.30	-.46	-.36	-.50	-.49

RELIABILITY AND LIMITATIONS OF ESTIMATING METHODS

Graphical comparisons of the standard errors for the individual methods of estimation and for the weighted-average estimates based on all three methods are shown in figures 3–7. The standard errors, expressed in percent, range from 43 to 107 for the basin-characteristics method, from 41 to 111 for the channel-width method, from 19 to 92 for the concurrent-measurement method, and from 15 to 43 for the weighted-average estimates based on all three methods. As indicated, the weighted-average estimates

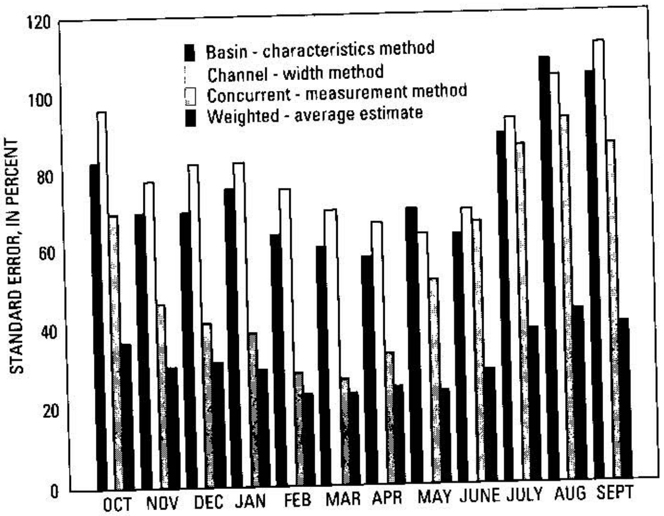

Figure 3. Standard error for daily mean discharge that was exceeded 90 percent of the time on the basis of different methods of estimation.

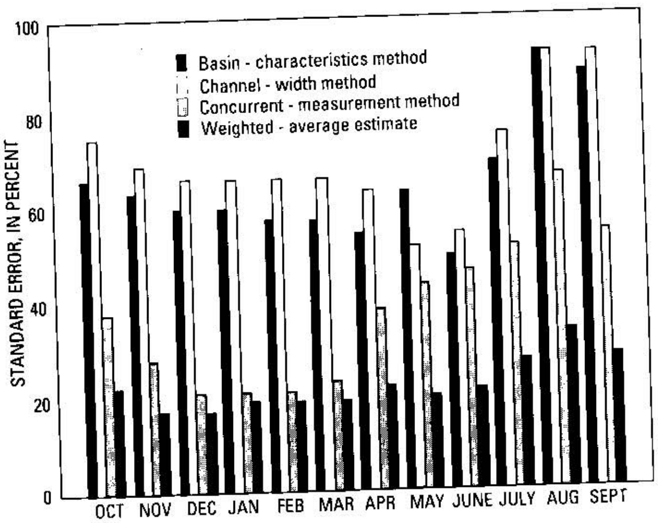

Figure 4. Standard error for daily mean discharge that was exceeded 70 percent of the time on the basis of different methods of estimation.

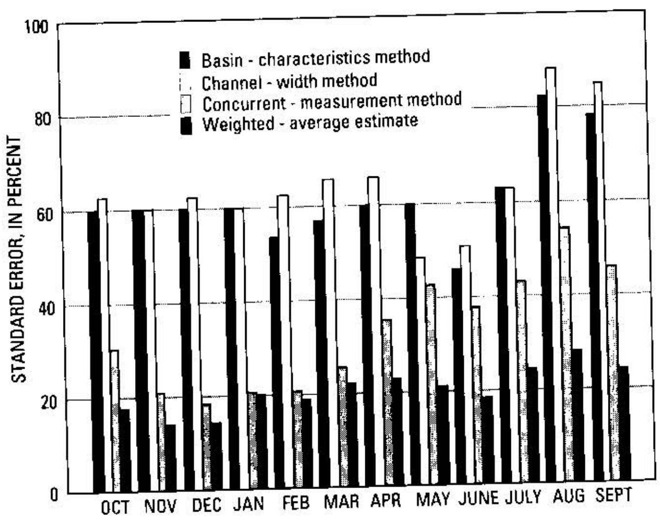

Figure 5. Standard error for daily mean discharge that was exceeded 50 percent of the time on the basis of different methods of estimation.

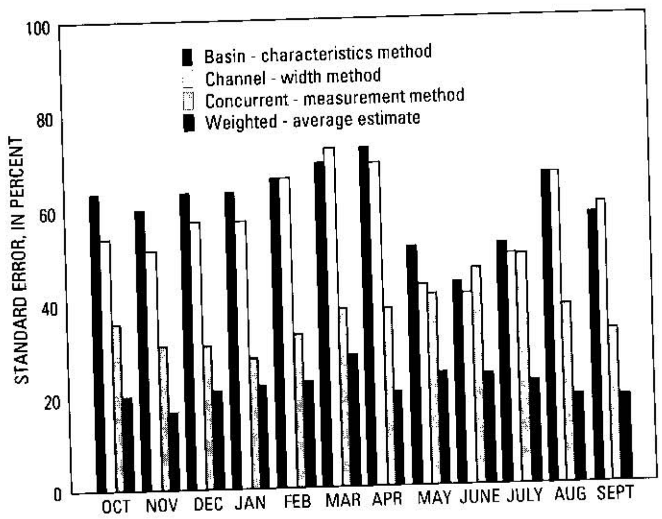

Figure 6. Standard error for daily mean discharge that was exceeded 10 percent of the time on the basis of different methods of estimation.

have the smallest standard errors for all monthly flow characteristics for all months. The weighted-average estimates thus are considered to be generally substantially more reliable than estimates from any of the three individual methods.

Although figures 3–7 indicate the general reliability of the different estimating methods, the reader needs to be aware of certain limitations associated with the individual methods that may limit their applicability. Both the basin-characteristics method and the channel-width method, for example, are based on regression analyses, and the resultant regression equations may not be applicable beyond the range of variable values used to derive the equations. The ranges of basin and climatic characteristics and channel widths used in this study are given in table 10. Extrapolation beyond the values listed may yield erroneous estimates. Regression equations based on basin characteristics are also generally not applicable to streams that receive their water from springs or that lose substantial flows because of permeable streambeds or other localized geologic features. The equations also may not be applicable to stream sites that have appreciable upstream lake storage or diversions.

Regression equations based on channel width are probably more reliable than equations based on basin characteristics in such instances, because channel width is formed by the recent flow regime, no matter how anoma-

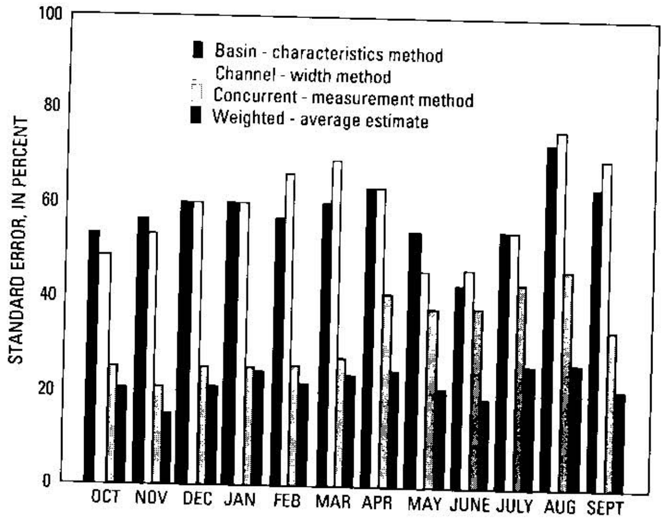

Figure 7. Standard error for mean monthly discharge based on different methods of estimation.

Table 10. Range of basin and climatic characteristics and channel widths used in the regression analyses

Basin or width characteristic	Range of values
Drainage area (A), in square miles	3.59 - 838
Percentage of basin above 6,000 feet elevation, plus 1 ($E6$)	1.00 - 101
Basin perimeter (PE), in miles	11.4 - 172
Basin slope (BSL), dimensionless	0.19 - 0.64
Mean annual precipitation (P), in inches	15 - 69
Mean basin elevation (E), in thousands of feet	4.10 - 7.60
Maximum basin relief (BR), in thousands of feet	2.04 - 7.09
Active-channel width (W_{AC}), in feet	12 - 172
Bankfull width (W_{BF}), in feet	16 - 192

lous the regime may be. Conversely, however, the channel-width method is generally not applicable where exposed bedrock occurs in either the streambed or banks, on braided or sand-channel streams, or on streams that have recently flooded or been altered by human activities.

In addition, accurate measurements of channel width require training and experience, and, even among experienced individuals, the variability in measured widths can be large. On the basis of a test in Wyoming, Wahl (1977) reported that the standard error in estimated flood discharge that could be attributed solely to measurement error might be as large as 30 percent. The total standard error of estimate for discharge based on the channel-width method thus is composed of both regression error and some unknown error in measurement.

Because the concurrent-measurement method is based only on measured streamflow, the method is generally applicable where a suitable flow-measurement section can be found and where a suitable, nearby, concurrent streamflow-gaging station is available. Thus, the method can be used for sites where neither the basin-characteristics method nor the channel-width method provides reliable estimates, but the reliability of the estimates made by use of the concurrent-measurement method is dependent on the degree of correlation between the measurement site and the correlating gaged site. If the concurrent measurements at the two sites are poorly correlated and show a large amount of scatter about the best-fit MOVE.1 line, the estimates made by use of the concurrent-measurement method may be unreliable. Extension of the MOVE.1 line beyond the range of discharge measurements may also result in errors in the long-term estimates. Additional limitations on the use of the concurrent-measurement method are the expense and time required to make the required 12 monthly flow measurements. Alternative measuring programs based on fewer measurements can be devised, but the standard errors of the method may increase substantially.

APPLICATION OF ESTIMATING METHODS

The general procedures for using all methods to make estimates of monthly flow characteristics and for weighting the individual estimates are illustrated in the following examples. The examples are varied to illustrate typical applications of the various methods.

Example 1.

Estimates of the daily mean discharges exceeded 90 and 10 percent of the time ($Q.90$ and $Q.10$) during July are required for a stream located within the study area. The basin perimeter (PE), maximum basin relief (BR), and basin slope (BSL) were measured on suitable topographic maps and determined to be 13.1 mi, 5.22 thousands of feet, and 0.55, respectively. The site was visited and the active-channel width (W_{AC}) was determined to be 16 ft. By use of the applicable basin-characteristics equations from table 2, the required monthly streamflow characteristics are calculated as follows:

$$Q.90 = 0.192\ PE^{1.37}\ BR^{0.96}\ BSL^{1.31}$$
$$Q.90 = 0.192\ (13.1)^{1.37}\ (5.22)^{0.96}\ (0.55)^{1.31}$$
$$\underline{Q.90 = 14.5\ \text{ft}^3/\text{s}}$$

$$Q.10 = 0.871\ PE^{1.35}\ BR^{1.01}\ BSL^{1.20}$$
$$Q.10 = 0.871\ (13.1)^{1.35}\ (5.22)^{1.01}\ (0.55)^{1.20}$$
$$\underline{Q.10 = 72.7\ \text{ft}^3/\text{s}}$$

Similarly, the required monthly streamflow characteristics are calculated from the applicable channel-width equations in table 3:

$$Q.90 = 0.162\ W_{AC}^{\ 1.51}$$
$$Q.90 = 0.162\ (16)^{1.51}$$
$$\underline{Q.90 = 10.7\ \text{ft}^3/\text{s}}$$

$$Q.10 = 0.857\ W_{AC}^{\ 1.51}$$
$$Q.10 = 0.857\ (16)^{1.51}$$
$$\underline{Q.10 = 56.4\ \text{ft}^3/\text{s}}$$

A program of once-monthly streamflow measurements was also instituted, and the measured flows were correlated with concurrent flows at a nearby, gaged correlating site as previously described. The MOVE.1 line through the plotted concurrent flows yielded the following estimates at the ungaged site:

$$Q.90 = 13.1\ \text{ft}^3/\text{s}$$
$$Q.10 = 53.0\ \text{ft}^3/\text{s}$$

Weights for July were determined from table 13 for all three methods. Weighted estimates were calculated as follows:

$$Q.90 = 14.5\ (0.294) + 10.7\ (0.210) + 13.1\ (0.496)$$
$$\underline{Q.90 = 13.0\ \text{ft}^3/\text{s}}$$

$$Q.10 = 72.7\ (0.006) + 56.4\ (0.496) + 53.0\ (0.498)$$
$$\underline{Q.10 = 54.8\ \text{ft}^3/\text{s}}$$

Example 2.

Estimates of the daily mean discharge exceeded 50 percent of the time ($Q.50$) and the mean monthly discharge (QM) for June are required for a site in the study area. Insufficient time was available to use the concurrent-measurement method. The following basin and climatic characteristics were measured from topographic and precipitation maps:

Drainage area (A) = 22.6 mi^2,
Basin slope (BSL) = 0.62,
Mean annual precipitation (P) = 40 in., and
Percentage of basin above 6,000 ft elevation, plus 1 ($E6$) = 61.0.

On a site visit, the bankfull width (W_{BF}) was measured as 35 ft.

By use of the applicable basin-characteristics equations in table 2, the required monthly flow characteristics were calculated as follows:

$$Q.50 = 0.245\ A^{0.91}\ BSL^{0.95}\ P^{0.95}\ E6^{0.19}$$
$$Q.50 = 0.245\ (22.6)^{0.91}\ (0.62)^{0.95}\ (40)^{0.95}\ (61.0)^{0.19}$$
$$\underline{Q.50 = 193\ \text{ft}^3/\text{s}}$$

$$QM = 0.284\ A^{0.90}\ BSL^{0.87}\ P^{0.92}\ E6^{0.19}$$
$$QM = 0.284\ (22.6)^{0.90}\ (0.62)^{0.87}\ (40)^{0.92}\ (61.0)^{0.19}$$
$$\underline{QM = 202\ \text{ft}^3/\text{s}}$$

By use of the appropriate channel-width equations in table 3, the monthly flow characteristics were calculated as follows:

$$Q.50 = 0.423\ W_{BF}^{\ 1.67}$$
$$Q.50 = 0.423\ (35)^{1.67}$$
$$\underline{Q.50 = 160\ \text{ft}^3/\text{s}}$$

$$QM = 0.445\ W_{BF}^{\ 1.68}$$
$$QM = 0.445\ (35)^{1.68}$$
$$\underline{QM = 175\ \text{ft}^3/\text{s}}$$

By use of the appropriate weights from table 13 for June, the weighted estimates based on the basin-characteristics method and the channel-width method were calculated as follows:

$$Q.50 = 193\ (0.572) + 160\ (0.428)$$
$$\underline{Q.50 = 179\ \text{ft}^3/\text{s}}$$

$$QM = 202\ (0.535) + 175\ (0.465)$$
$$\underline{QM = 189\ \text{ft}^3/\text{s}}$$

Example 3.

Estimates of mean monthly discharge for January and February are required for a site in the study area. The following basin characteristics were measured from available topographic and precipitation maps:

Drainage area (A) = 21.0 mi^2,
Maximum basin relief (BR) = 4.01 thousands of feet, and
Basin slope (BSL) = 0.37.

On a site visit, the active-channel width (W_{AC}) was measured as 30 ft. During the site visit, the stream appeared to receive its water from a spring because streamflow was greater than at nearby, similar streams in the area. A concurrent-measurement program was instituted, and the 12 visits for measurements also confirmed that the site had greater flows than nearby, similar streams. On the basis of the concurrent-measurement program, estimates of the required monthly flow characteristics were as follows:

QM for January = 22.5 ft^3/s
QM for February = 24.2 ft^3/s

By use of the appropriate basin-characteristics equations in table 2, mean monthly flow estimates were calculated as follows:

$$QM \text{ for January} = 0.424\ A^{0.96}\ BR^{0.88}\ BSL^{1.30}$$
$$QM \text{ for January} = 0.424\ (21.0)^{0.96}\ (4.01)^{0.88}\ (0.37)^{1.30}$$
$$\underline{QM \text{ for January} = 7.35\ \text{ft}^3/\text{s}}$$

$$QM \text{ for February} = 0.590\ A^{1.03}\ BR^{0.63}\ BSL^{1.53}$$
$$QM \text{ for February} = 0.590\ (21.0)^{1.03}\ (4.01)^{0.63}\ (0.37)^{1.53}$$
$$\underline{QM \text{ for February} = 7.11\ \text{ft}^3/\text{s}}$$

By use of the appropriate channel-width equations in table 3, the estimates of mean monthly flow were calculated as follows:

$$QM \text{ for January} = 0.0509\, W_{AC}^{1.73}$$
$$QM \text{ for January} = 0.0509\, (30)^{1.73}$$
$$\underline{QM \text{ for January} = 18.3 \text{ ft}^3/\text{s}}$$

$$QM \text{ for February} = 0.0476\, W_{AC}^{1.75}$$
$$QM \text{ for February} = 0.0476\, (30)^{1.75}$$
$$\underline{QM \text{ for February} = 18.3 \text{ ft}^3/\text{s}}$$

Because the flow estimates made from the basin-characteristics equations were substantially smaller than the estimates made from the other two methods, and because the site appeared to receive its water from a spring during the site visits, the basin-characteristics estimates were considered to be erroneous. The final weighted estimates of mean monthly flow thus were made by using only the concurrent-measurement method estimates and the channel-width method estimates from table 13 for January and February as follows:

$$QM \text{ for January} = 18.3\, (0.060) + 22.5\, (0.940)$$
$$\underline{QM \text{ for January} = 22.2 \text{ ft}^3/\text{s}}$$

$$QM \text{ for February} = 18.3\, (0.136) + 24.2\, (0.864)$$
$$\underline{QM \text{ for February} = 23.4 \text{ ft}^3/\text{s}}$$

The above examples were selected to illustrate how the various methods for estimating monthly streamflow characteristics could be used and combined in typical applications to provide the most reliable estimates. Considerable judgment is required to decide which methods may be appropriate or cost and time effective, however. Situations requiring the most accurate and reliable estimates will almost always require use of the concurrent-measurement method, but the additional time and cost required may be prohibitive.

SUMMARY AND CONCLUSIONS

Three methods for estimating mean monthly discharge and various points on the daily mean flow-duration curve for each month (daily mean discharges that were exceeded 90, 70, 50, and 10 percent of the time each month) were developed for western Montana. The first method was based on a multiple-regression analysis that related the streamflow characteristics to various basin and climatic variables. Several new basin characteristics were measured and tested to determine whether the regression equations might be improved. New characteristics that were found to be significant were basin perimeter, basin slope, and maximum basin relief. The estimating equations based on basin characteristics had standard errors ranging from 43 to 107 percent. The standard error was smallest in the estimating equations for daily mean discharge that was exceeded 10 percent of the time ($Q.10$) for June and for mean monthly discharge for June. The standard error was largest in the estimating equations for daily mean discharge that was exceeded 90 percent of the time ($Q.90$) for August. Regression equations based on basin and climatic characteristics are generally not applicable to streams that receive or lose water as a result of localized geologic features. They also may not be applicable to stream sites having appreciable upstream storage or diversions.

The second method for estimating monthly streamflow characteristics was based on a regression analysis relating the streamflow characteristics to channel width. The channel-width features used were active-channel width (W_{AC}) and bankfull width (W_{BF}). Most of the derived regression equations were based on active-channel width, but the equations for May and June were based on bankfull width. The standard errors for the estimating equations based on channel width ranged from 41 to 111 percent. The standard error was smallest in the estimating equation for daily mean discharge that was exceeded 10 percent of the time ($Q.10$) during June and was largest in the estimating equation for daily mean discharge that was exceeded 90 percent of the time ($Q.90$) in September. Regression equations based on channel width are generally not applicable where bedrock is exposed in the channel, on braided or sand-channel streams, or on streams that have recently been altered by floods or human activities. Proper application of the channel-width method also requires training and experience.

The third method for estimating monthly streamflow characteristics, termed the "concurrent-measurement method," required 12 once-monthly measurements of streamflow at the ungaged site of interest. The streamflow measurements at the ungaged site were correlated with concurrent discharges at a nearby gaged site by use of a MOVE.1 curve-fitting technique. The relation between flows at the two sites defined by the MOVE.1 curve then was used to compute the required monthly flow characteristics at the ungaged site from the monthly flow characteristics at the gaged site. Standard errors for the concurrent-measurement method were estimated by applying the method to 20 gaged sites and computing the standard deviation of the differences between the monthly flow characteristics determined from the estimation method and the monthly flow characteristics determined from the actual flow record. On this basis, the standard errors of the concurrent-measurement method ranged from 19 to 92 percent. The standard error was smallest in the estimate for the daily mean discharge that was exceeded 50 percent of the time ($Q.50$) during December and was largest in the estimate for the daily mean discharge that was exceeded 90 percent of the time ($Q.90$) during August. Although the concurrent-measurement method is generally substantially more accurate than either the basin-characteristics method or the channel-width method, it may yield unreliable results if there is poor correlation between the measurement site and the correlating gaged site. In addition, the monthly flow measurement method may be too expensive and time consuming for some applications.

A procedure for weighting individual estimates from any combination of the three different estimating methods to provide a minimum-variance weighted-average estimate also was developed. The standard errors for the weighted estimates of monthly flow characteristics when all three methods were used ranged from 15 to 43 percent. The standard error was smallest for the weighted estimates for the daily mean discharge that was exceeded 50 percent of the time ($Q.50$) during November and December and was largest for the daily mean discharge that was exceeded 90 percent of the time ($Q.90$) during August.

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SUPPLEMENTAL DATA

Table 11. Monthly streamflow characteristics for selected streamflow-gaging stations

[Monthly streamflow characteristic: *Q*.90, daily mean discharge exceeded 90 percent of the time; *Q*.70, daily mean discharge exceeded 70 percent of the time; *Q*.50, daily mean discharge exceeded 50 percent of the time; *Q*.10, daily mean discharge exceeded 10 percent of the time; *QM*, mean monthly discharge; --, no data]

Gaging station	Monthly streamflow characteristic, in cubic feet per second, for specified month														
	October					November					December				
	Q.90	Q.70	Q.50	Q.10	QM	Q.90	Q.70	Q.50	Q.10	QM	Q.90	Q.70	Q.50	Q.10	QM
06024500	16.0	19.1	21.7	29.8	21.8	14.1	17.0	19.4	30.7	21.0	10.6	13.8	16.6	21.4	15.6
06029000	2.1	2.7	4.1	15.9	7.3	1.6	2.1	2.3	3.6	2.6	1.3	1.7	2.0	3.0	2.1
06030500	1.5	1.9	2.3	3.9	2.4	1.4	1.8	2.2	3.2	2.2	1.1	1.4	1.8	3.0	1.9
06033000	13.7	22.7	31.7	66.7	36.0	17.8	26.6	33.2	54.3	34.4	15.5	23.0	28.0	42.4	28.1
06061500	18.0	23.1	30.7	58.2	32.7	18.5	23.4	28.3	47.7	30.7	14.9	20.9	25.5	37.9	25.1
06062500	.4	.6	1.1	8.1	3.0	.4	.7	1.3	5.6	2.2	.3	.7	1.1	4.4	1.8
06073000	15.9	28.2	39.7	80.7	43.7	25.2	30.4	37.6	82.7	44.8	22.1	27.5	33.7	67.3	39.2
06078500	73.9	88.4	106	185	122	65.4	79.3	93.3	148	102	54.4	66.5	75.1	124	83.0
06081500	3.2	7.0	12.5	25.7	12.7	4.3	8.8	12.0	21.5	12.1	4.9	7.0	9.3	17.3	10.2
12300500	8.8	10.8	13.9	80.3	27.3	9.0	11.6	17.0	55.8	25.0	8.4	11.6	18.8	44.1	23.8
12301300	69.0	87.1	103	163	114	73.6	94.6	108	169	118	68.1	82.5	96.0	158	108
12301999	7.3	8.8	10.3	14.3	10.5	7.9	9.1	10.8	17.0	11.4	7.0	8.5	9.6	23.1	12.0
12302055	94.0	112	125	182	132	103	127	147	294	174	97.9	132	163	366	223
12302500	6.7	10.5	18.8	60.7	27.4	7.8	15.4	24.4	63.4	32.6	11.6	16.6	22.1	71.5	38.8
12303100	5.4	6.8	8.0	15.2	9.0	6.0	7.7	9.2	19.3	11.5	5.3	6.5	7.8	15.6	10.8
12324100	24.4	27.6	30.0	49.3	33.2	18.7	22.2	24.8	36.0	25.3	16.5	19.4	21.6	29.3	21.5
12330000	13.5	19.0	23.8	38.6	24.7	16.7	21.0	24.2	34.7	24.8	14.8	19.4	21.5	30.0	21.9
12332000	35.9	41.9	46.5	68.7	51.6	28.5	36.3	41.1	64.0	43.8	23.4	30.3	35.0	52.1	36.4
12335000	111	144	162	204	159	111	130	150	194	149	93.3	120	135	173	132
12338690	37.1	41.8	45.4	60.3	46.4	34.7	38.7	41.8	61.0	45.6	31.2	35.1	38.3	84.3	45.2
12339450	51.3	61.4	75.3	123	81.7	54.4	66.7	74.3	156	86.1	63.2	70.2	76.6	180	99.8
12343400	83.6	97.5	108	151	113	72.3	89.7	102	142	104	52.7	75.0	87.5	126	92.4
12346500	30.7	36.2	41.2	53.9	41.5	26.9	31.3	35.1	45.8	35.4	23.0	26.3	29.0	39.1	30.0
12347500	3.5	8.8	16.8	59.7	27.3	5.6	12.2	18.3	56.6	25.6	6.2	11.6	16.6	42.4	22.2
12350000	2.9	6.4	14.1	55.2	22.2	5.7	11.2	15.4	51.2	22.5	5.2	8.4	13.7	40.2	19.2
12350500	5.9	15.8	27.9	85.4	40.4	7.1	16.5	23.4	74.1	33.5	6.1	12.5	14.8	41.6	21.1
12351000	15.8	17.9	20.2	31.8	21.8	16.0	18.2	20.9	33.3	22.3	14.3	17.3	19.3	27.9	19.6
12352000	15.0	39.0	52.1	138	65.1	26.4	53.5	75.7	179	88.9	39.4	54.1	66.3	163	87.3
12353280	23.1	29.0	31.3	39.2	30.9	22.5	28.5	31.7	44.7	32.2	23.3	27.2	31.4	82.9	42.7
12354000	89.8	108	122	207	143	99.2	118	153	519	235	86.9	105	143	431	214
12356500	8.8	10.9	17.5	37.7	21.9	8.7	14.4	18.1	27.5	18.4	7.3	10.8	12.9	26.4	16.1
12357000	148	187	225	678	347	132	177	280	702	355	121	166	246	643	333
12359000	261	316	433	1090	623	253	323	444	880	529	214	288	369	832	452
12359500	43.8	48.5	60.8	179	93.7	41.3	50.9	83.2	168	93.9	36.9	49.3	69.4	145	81.6
12360000	8.7	12.0	18.9	59.4	29.2	8.7	15.0	31.5	69.9	34.9	10.4	18.3	27.5	57.3	36.3
12360500	6.7	8.0	10.9	48.2	21.6	5.7	8.0	23.1	56.7	26.1	4.2	9.0	19.8	43.1	23.4
12361000	22.5	31.5	55.2	199	89.3	25.5	51.5	74.5	190	96.5	23.1	37.8	58.7	158	80.4
12361500	10.1	20.9	39.9	147	63.4	12.1	34.6	54.0	116	60.3	14.0	27.8	41.8	103	54.1
12364000	5.7	10.8	14.6	62.0	38.3	11.8	14.8	18.7	36.2	20.9	12.5	15.6	19.5	41.6	22.5
12365000	67.1	89.8	110	142	110	71.4	95.8	113	180	121	65.4	81.8	94.6	167	107
12365800	25.1	31.5	37.0	48.9	36.2	18.5	26.4	32.2	69.8	37.3	11.5	21.3	26.5	58.7	34.3
12366000	22.1	50.6	68.6	127	70.7	26.8	57.1	70.3	122	73.7	40.1	51.0	59.1	123	71.8
12369200	37.2	44.4	51.2	85.9	56.4	35.0	45.2	52.1	91.0	58.4	34.7	41.6	46.4	102	59.5
12370000	350	416	507	860	560	358	444	529	846	582	350	425	484	862	567
12376000	15.8	22.6	27.9	53.3	31.9	11.5	22.2	29.0	50.8	31.4	7.4	18.3	22.9	35.2	22.4
12378000	30.1	38.3	44.7	57.7	43.5	25.2	28.5	330	47.6	34.0	13.8	20.7	24.9	37.1	24.3
12378500	31.7	35.7	42.3	59.7	43.1	28.9	36.6	45.5	71.4	47.7	26.6	30.0	35.4	51.5	37.1
12379500	28.0	33.1	41.0	78.4	47.8	32.0	50.0	56.3	70.0	54.1	24.7	43.7	49.5	55.5	45.0
12381000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12381400	21.0	24.0	26.0	68.4	34.4	19.0	23.0	26.0	38.8	27.6	6.0	13.0	17.0	22.0	15.5
12381500	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12382000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12382500	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12383500	6.8	9.1	9.7	11.4	9.3	6.0	7.7	8.1	9.3	7.9	6.3	6.9	7.3	8.7	7.3
12385000	4.9	5.9	6.8	8.9	7.6	--	--	--	--	--	--	--	--	--	--
12388500	7.2	7.9	8.4	14.3	9.6	7.6	8.1	11.1	14.7	10.6	6.6	7.5	8.0	12.7	10.0
12389500	140	173	189	241	191	146	168	185	247	194	128	157	179	305	203
12390700	43.3	51.4	56.9	68.0	59.7	41.1	47.9	52.8	122	69.7	41.4	48.9	57.8	228	113
12391550	76.8	91.8	102	135	103	80.2	95.6	116	267	157	79.0	109	182	551	282

Table 11. Monthly streamflow characteristics for selected streamflow-gaging stations—Continued

Gaging station	Monthly streamflow characteristic, in cubic feet per second, for specified month														
	January					February					March				
	Q.90	Q.70	Q.50	Q.10	QM	Q.90	Q.70	Q.50	Q.10	QM	Q.90	Q.70	Q.50	Q.10	QM
06024500	9.6	12.3	14.8	20.5	14.2	8.6	11.5	12.7	27.7	14.9	9.5	13.3	14.8	23.1	15.5
06029000	.5	1.4	1.6	2.0	1.4	1.5	1.8	1.9	2.3	1.8	1.1	1.7	1.8	2.6	1.8
06030500	.9	1.4	1.7	2.6	1.7	1.0	1.4	1.8	2.4	1.7	.9	1.5	2.0	4.1	2.1
06033000	14.7	21.6	27.4	38.8	26.1	16.2	24.1	29.1	41.3	29.7	24.2	30.5	36.1	73.3	45.4
06061500	13.5	19.8	23.2	32.6	22.2	15.1	20.8	24.0	37.0	25.0	17.4	24.2	29.2	50.1	32.0
06062500	.3	.7	1.1	3.1	1.5	.4	.7	1.1	3.0	1.4	.5	1.0	1.6	5.6	2.4
06073000	20.1	23.9	28.2	52.1	32.6	19.9	23.6	27.8	49.5	31.1	22.2	26.4	30.8	51.2	36.4
06078500	46.6	56.7	64.6	89.6	66.6	47.3	56.3	65.0	87.4	66.3	46.8	55.3	61.5	92.0	67.7
06081500	4.0	6.0	7.2	18.3	10.1	3.3	6.4	7.9	22.7	14.1	5.8	9.3	12.8	30.8	15.8
12300500	8.0	11.0	20.6	32.7	19.1	7.7	15.0	20.2	52.0	27.9	13.1	19.3	28.9	45.0	33.7
12301300	61.7	75.4	90.6	144	101	64.5	80.2	96.4	150	103	75.3	94.7	114	203	138
12301999	4.7	8.2	10.7	26.0	22.2	5.5	9.5	13.4	58.3	26.6	11.1	15.8	31.8	127	68.8
12302055	86.0	126	173	437	265	119	158	210	679	308	172	238	356	1120	529
12302500	9.9	15.4	19.1	33.1	20.0	8.6	12.3	14.7	50.5	24.6	11.7	15.8	22.0	55.6	29.8
12303100	4.6	5.8	7.2	14.0	9.7	4.6	5.7	7.0	17.8	10.1	4.8	6.2	8.3	19.1	10.7
12324100	16.4	18.6	20.8	26.0	20.4	16.6	18.5	20.0	24.5	19.8	16.6	18.3	19.7	24.4	19.8
12330000	12.3	17.4	19.7	25.5	19.2	13.9	17.4	19.2	24.6	19.0	15.1	17.3	18.8	24.6	18.9
12332000	20.0	26.0	30.1	45.5	31.5	19.2	27.4	31.9	45.0	32.0	22.4	28.9	33.3	49.0	35.2
12335000	82.7	108	125	155	119	90.0	106	120	157	121	93.9	106	116	156	125
12338690	27.6	32.9	36.9	86.2	46.9	28.0	33.1	37.9	69.3	43.5	29.2	34.4	51.9	93.9	55.9
12339450	58.1	67.7	77.3	179	94.7	51.3	65.0	77.3	140	84.5	61.1	78.9	96.8	198	124
12343400	57.9	71.4	81.1	118	85.6	65.7	75.6	82.9	132	94.1	72.8	85.3	95.7	180	112
12346500	20.0	23.6	26.3	36.1	27.0	20.4	23.4	25.6	32.1	25.7	20.6	23.6	25.7	34.3	26.2
12347500	6.4	8.4	11.4	27.8	14.7	6.3	9.3	13.2	25.7	15.4	7.6	12.1	15.5	30.4	17.6
12350000	5.2	7.7	11.8	21.8	12.7	5.4	8.1	11.4	19.5	11.9	6.8	11.1	13.4	24.5	15.6
12350500	6.9	10.1	11.7	22.6	13.1	7.9	10.5	13.8	34.7	18.7	9.6	14.8	17.7	28.7	18.8
12351000	11.7	14.9	16.8	22.8	16.7	11.9	14.6	16.6	22.4	16.4	11.5	14.6	16.0	23.3	16.8
12352000	37.6	52.9	60.3	150	76.8	49.7	61.5	72.5	141	90.9	48.3	64.3	91.2	161	101
12353280	19.1	23.3	30.4	66.5	53.7	23.0	29.1	35.4	91.1	47.6	33.0	48.0	84.6	187	109
12354000	88.7	129	169	487	282	114	162	215	610	305	138	206	307	854	412
12356500	6.3	7.7	9.8	16.7	10.9	6.1	7.1	8.1	15.2	9.6	6.3	7.0	8.6	15.7	10.0
12357000	112	148	197	387	223	112	148	203	394	238	130	171	211	394	251
12359000	220	271	321	518	349	223	283	328	595	386	237	309	352	544	395
12359500	31.1	47.2	56.6	102	61.0	31.8	42.6	51.0	91.7	63.0	34.7	46.9	57.1	92.2	61.8
12360000	9.2	17.1	20.6	41.4	23.1	12.3	17.5	20.1	44.0	26.7	15.5	19.7	28.7	46.3	30.6
12360500	3.6	9.5	13.2	26.9	14.2	5.8	11.0	12.8	27.8	15.6	8.5	10.6	14.7	27.0	16.2
12361000	23.5	36.0	45.0	110	63.9	24.4	36.1	45.1	131	69.0	31.0	41.6	53.1	142	75.0
12361500	13.7	22.5	26.9	53.0	31.1	16.0	20.2	24.0	53.0	31.4	17.1	21.2	25.1	44.6	28.7
12364000	8.4	15.4	21.7	45.1	22.2	9.7	13.4	18.4	49.5	20.6	14.7	18.0	20.3	46.6	25.6
12365000	60.5	75.4	88.7	144	108	63.3	76.9	89.4	137	99.2	77.9	93.5	113	223	140
12365800	8.0	13.4	18.9	79.0	30.0	11.1	14.6	18.7	59.2	26.0	14.6	17.9	25.3	68.4	34.0
12366000	34.0	47.8	58.6	121	68.9	35.3	48.9	59.6	122	67.7	52.7	66.4	79.3	153	95.7
12369200	29.6	37.3	47.4	78.0	54.4	30.2	36.2	42.9	70.5	47.6	33.8	39.3	50.4	92.8	59.8
12370000	335	390	453	681	499	311	376	436	699	491	335	431	500	935	588
12376000	--	--	--	--	--	--	--	--	--	--	20.1	25.5	39.0	70.7	43.4
12378000	10.3	15.1	16.5	28.4	17.4	9.9	12.3	13.9	19.4	13.7	11.1	12.5	13.9	19.4	14.4
12378500	19.9	22.8	26.6	43.6	27.6	20.5	23.1	26.2	43.5	28.1	22.8	28.1	32.4	39.9	32.1
12379500	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12381000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12381400	10.0	12.0	17.0	30.0	18.0	10.7	14.0	15.0	17.0	14.3	14.0	15.0	17.0	20.3	17.6
12381500	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12382000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12382500	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12383500	4.9	5.3	6.0	6.9	5.9	4.3	4.5	4.6	5.1	4.6	4.2	4.6	5.0	5.7	5.0
12385000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12388500	5.6	6.6	7.4	33.0	15.2	3.3	6.1	7.4	8.6	6.6	4.0	7.1	7.9	34.3	13.0
12389500	123	148	179	303	213	134	161	196	389	242	155	202	262	535	334
12390700	41.7	53.7	78.2	215	128	43.4	68.2	104	312	154	63.0	117	165	389	215
12391550	73.0	126	170	420	261	100	128	154	489	246	152	201	257	510	300

Table 11. Monthly streamflow characteristics for selected streamflow-gaging stations—Continued

Gaging station	April					May					June				
	Monthly streamflow characteristic, in cubic feet per second, for specified month														
	Q.90	Q.70	Q.50	Q.10	QM	Q.90	Q.70	Q.50	Q.10	QM	Q.90	Q.70	Q.50	Q.10	QM
06024500	16.0	26.6	45.4	208	81.2	80.2	251	434	711	409	108	180	269	693	340
06029000	2.3	2.8	3.5	5.5	3.6	3.9	5.4	8.3	67.0	22.9	19.6	27.9	36.4	78.4	41.9
06030500	2.3	4.7	11.7	45.5	18.2	12.1	26.8	44.9	88.8	49.9	11.5	17.5	27.2	70.0	34.9
06033000	43.2	72.1	117	392	169	172	282	395	909	484	90.4	218	346	939	434
06061500	27.0	38.7	48.5	95.2	54.5	52.8	79.2	102	188	118	49.3	81.0	116	274	144
06062500	1.9	4.8	9.4	46.5	17.5	22.2	44.8	71.0	183	88.7	10.4	26.4	54.9	194	79.9
06073000	26.8	42.9	71.2	328	129	106	201	318	737	375	72.0	204	345	967	451
06078500	67.1	93.1	121	505	225	351	749	1170	2400	1260	648	1080	1390	2590	1543
06081500	8.7	13.1	22.0	43.7	23.8	10.8	31.1	48.4	142	67.5	8.1	30.4	55.9	239	98.7
12300500	47.6	88.3	223	611	273	130	208	360	754	412	42.1	69.8	105	245	125
12301300	136	205	302	760	380	437	607	771	1260	808	405	607	742	1230	783
12301999	28.9	70.4	130	656	263	50.0	164	261	580	296	18.0	46.4	64.1	168	82.2
12302055	313	553	818	2240	1110	646	1330	1450	2690	1570	330	637	856	1580	910
12302500	39.5	61.9	85.8	226	116	110	156	215	399	234	101	150	207	374	224
12303100	9.4	14.5	20.4	59.6	28.3	33.3	53.3	78.0	153	86.0	41.6	67.9	91.4	161	96.3
12324100	18.0	21.0	23.5	39.2	26.3	32.0	49.8	86.2	198	101	112	174	222	341	221
12330000	17.3	20.5	24.2	52.7	29.6	36.7	62.2	94.4	249	121	75.6	126	178	333	191
12332000	30.6	39.8	53.2	146	73.0	101	196	290	693	347	229	357	463	840	509
12335000	103	133	170	577	271	125	517	806	2070	970	458	756	1130	2370	1264
12338690	45.3	77.8	130	490	211	250	404	592	1250	668	271	501	667	1380	746
12339450	89.3	241	431	1240	579	562	847	1070	1810	1140	361	622	769	1250	792
12343400	111	158	206	469	248	355	568	869	1740	972	437	812	1080	1900	1160
12346500	24.8	30.9	39.2	98.3	51.3	64.0	120	190	474	233	170	320	397	562	386
12347500	20.7	34.9	51.6	165	75.3	97.5	157	240	457	254	137	196	257	427	269
12350000	17.1	36.9	62.4	171	81.1	85.7	151	229	468	252	108	158	218	430	243
12350500	25.0	43.8	63.2	184	83.6	87.2	148	213	454	246	147	212	291	508	309
12351000	16.6	22.2	31.3	85.5	42.1	46.9	76.0	106	277	139	74.9	118	167	302	180
12352000	96.9	202	314	663	372	412	650	809	1260	838	316	483	630	1030	652
12353280	70.5	120	231	551	271	140	328	453	821	479	93.0	213	290	633	339
12354000	472	784	1080	2290	1240	929	1510	1970	3830	2210	468	833	1320	3060	1542
12356500	9.0	24.0	47.9	140	63.9	90.8	141	174	304	187	44.0	64.3	113	246	127
12357000	285	600	906	2940	1322	1840	2880	4130	7440	4350	1230	2180	3170	7580	3800
12359000	476	771	1290	3780	1760	2520	4110	6380	12000	6800	3400	5680	7730	12700	7950
12359500	73.4	119	253	880	394	504	1040	1480	2830	1590	487	1020	1340	2580	1449
12360000	43.0	88.0	158	452	205	245	377	477	931	545	121	247	358	696	385
12360500	26.3	41.6	83.5	250	112	140	212	263	466	284	76.3	141	202	395	219
12361000	72.8	137	204	586	272	369	584	780	1440	837	369	538	713	1360	797
12361500	27.9	46.7	86.5	266	117	130	271	395	784	429	264	391	504	837	532
12364000	30.7	64.1	108	332	167	83.1	203	296	610	341	38.0	84.1	114	297	141
12365000	125	248	400	1290	586	445	847	1170	1990	1213	311	577	811	1570	880
12365800	24.0	68.8	105	365	152	260	387	481	796	507	171	321	427	911	499
12366000	78.5	128	175	421	216	296	416	517	848	540	291	474	611	928	621
12369200	46.1	86.9	145	394	186	206	311	397	739	435	295	387	467	818	520
12370000	608	922	1330	2690	1500	1580	2160	2760	4530	2910	1890	2630	3240	5120	3390
12376000	17.7	33.2	48.2	106	55.9	37.5	86.8	137	244	139	133	219	269	450	302
12378000	12.8	17.0	22.6	53.2	28.6	25.9	53.0	78.6	174	88.5	120	199	229	380	273
12378500	26.4	30.9	37.6	72.6	44.7	--	--	--	--	--	--	--	--	--	--
12379500	31.8	43.0	53.0	90.5	56.8	43.5	71.4	102	220	120	162	221	273	406	283
12381000	--	--	--	--	--	32.8	41.1	59.0	102	60.2	36.3	42.7	70.0	105	68.0
12381400	15.6	21.0	62.0	125	62.7	75.0	143	194	387	217	145	196	269	446	280
12381500	--	--	--	--	--	--	--	--	--	--	196	253	361	590	378
12382000	--	--	--	--	--	93.2	134	175	370	200	104	168	231	363	235
12382500	--	--	--	--	--	12.2	16.9	31.5	86.0	41.5	27.3	36.0	45.5	92.2	51.2
12383500	4.4	4.9	5.4	9.1	5.8	7.7	9.2	12.6	28.0	15.4	21.2	28.0	31.6	43.0	32.5
12385000	--	--	--	--	--	11.2	16.7	23.4	54.2	28.4	27.4	36.8	44.3	83.5	50.2
12388500	16.5	29.1	47.5	88.1	49.9	52.1	71.9	96.9	183	110	34.0	52.2	81.0	207	105
12389500	279	437	620	1400	769	629	1030	1360	2430	1450	496	788	1040	2070	1160
12390700	171	283	420	924	499	415	648	825	1490	902	228	377	543	1150	615
12391550	206	328	442	991	531	562	804	1030	1680	1080	424	659	900	1880	1030

Table 11. Monthly streamflow characteristics for selected streamflow-gaging stations—Continued

Gaging station	Monthly streamflow characteristic, in cubic feet per second, for specified month														
	July					August					September				
	Q.90	Q.70	Q.50	Q.10	QM	Q.90	Q.70	Q.50	Q.10	QM	Q.90	Q.70	Q.50	Q.10	QM
06024500	32.8	42.8	55.8	102	61.6	17.4	21.4	24.8	39.2	26.2	14.9	17.2	19.7	30.9	21.0
06029000	13.4	19.2	24.9	40.2	25.1	17.9	20.7	28.0	40.3	27.7	7.9	15.2	18.0	26.7	17.4
06030500	2.5	3.8	5.5	17.1	7.8	1.3	1.8	2.2	4.6	2.5	1.4	1.7	2.0	3.3	2.2
06033000	13.4	33.0	60.3	211	93.9	7.6	13.5	19.8	56.8	26.5	7.5	15.2	21.7	47.9	26.7
06061500	20.9	34.8	50.5	125	61.1	13.9	21.2	28.3	56.5	31.2	15.0	20.7	26.5	56.1	30.5
06062500	.7	2.1	5.2	34.7	12.7	.3	.6	1.2	6.1	2.3	.3	.5	.9	5.3	2.0
06073000	20.1	43.3	84.0	287	123	12.6	20.0	31.3	95.6	47.5	11.2	21.2	27.9	62.9	34.6
06078500	199	275	373	935	483	114	138	156	241	167	84.8	100	115	169	124
06081500	1.8	11.3	25.2	82.1	39.0	1.6	7.4	15.5	39.8	17.9	2.7	6.6	11.0	30.0	13.2
12300500	15.8	22.3	30.8	69.5	36.3	7.9	9.8	14.1	27.3	16.4	7.3	9.0	10.2	20.7	12.2
12301300	133	208	281	563	319	69.4	104	127	195	130	71.4	92.5	112	158	115
12301999	6.9	15.8	21.8	57.1	29.6	4.7	10.0	12.2	17.8	11.4	4.9	8.0	9.1	13.0	9.2
12302055	126	208	276	586	313	81.4	113	145	213	144	90.1	112	126	162	130
12302500	27.0	42.8	56.4	136	71.6	9.5	14.6	20.4	37.7	21.6	7.2	10.1	13.0	35.8	18.3
12303100	11.6	18.1	25.9	63.5	31.9	6.1	8.2	10.4	16.8	10.6	5.8	7.0	8.1	12.2	8.7
12324100	65.5	84.1	97.7	160	105	45.1	57.0	68.5	98.1	68.9	28.7	35.2	40.8	62.6	43.2
12330000	20.9	38.2	52.4	132	65.7	9.1	14.7	19.5	41.7	22.4	8.1	12.8	17.4	34.5	19.2
12332000	76.7	119	161	349	191	42.6	57.6	68.7	107	72.4	36.3	44.4	51.2	75.4	53.0
12335000	222	311	417	943	500	145	185	224	359	235	121	154	172	226	173
12338690	83.4	139	193	463	247	53.0	71.3	81.5	115	82.6	37.7	48.3	55.3	70.9	55.1
12339450	78.9	147	230	530	274	42.4	60.8	79.8	148	87.0	38.4	48.6	57.9	127	75.4
12343400	144	202	266	561	313	82.7	106	126	189	131	84.5	95.4	110	161	116
12346500	73.8	101	127	280	153	43.9	54.8	65.4	97.9	67.9	35.3	41.0	46.1	62.5	47.6
12347500	24.9	45.2	70.2	195	90.7	7.4	14.0	20.7	36.8	21.1	3.9	6.6	11.7	30.8	16.5
12350000	17.4	33.9	57.2	192	84.2	4.3	7.3	10.3	24.8	12.7	2.6	3.9	6.0	23.0	10.7
12350500	38.2	65.9	100	247	125	10.3	14.7	19.1	42.7	24.1	6.6	9.2	13.2	33.6	18.0
12351000	29.7	41.3	51.9	123	65.8	19.8	23.6	29.1	42.7	29.5	16.4	19.5	21.7	28.9	21.9
12352000	60.4	118	176	424	211	18.7	31.9	47.7	84.8	49.7	14.0	23.8	40.0	76.0	42.9
12353280	38.1	73.7	96.6	179	104	22.0	34.2	41.3	59.9	41.5	21.1	30.2	34.4	44.5	33.4
12354000	178	242	313	746	400	106	132	155	240	165	92.4	110	127	177	132
12356500	15.8	21.6	28.4	88.2	39.1	10.2	12.8	15.6	25.1	16.1	9.3	10.8	12.0	19.7	13.4
12357000	363	535	747	2090	1041	194	254	306	495	326	170	201	227	339	244
12359000	969	1450	2080	5290	2720	431	546	648	1140	730	305	357	412	825	500
12359500	140	227	338	960	470	66.6	92.5	115	178	119	52.5	61.5	68.3	104	75.7
12360000	31.3	44.7	65.0	169	86.7	14.1	18.2	22.5	35.2	23.1	10.3	12.3	13.9	25.0	17.9
12360500	24.4	35.7	56.9	130	68.9	12.3	15.2	17.8	27.9	18.9	8.1	9.3	10.7	16.5	11.4
12361000	75.0	107	151	382	197	35.4	44.5	54.2	91.2	60.0	27.0	32.7	38.3	104	59.2
12361500	55.4	88.4	149	373	193	22.1	27.9	34.7	71.0	41.1	13.5	17.7	23.2	63.7	33.2
12364000	8.3	23.9	40.1	126	55.6	3.9	7.1	9.6	34.2	15.7	2.4	6.3	8.8	29.1	12.5
12365000	127	230	333	665	370	68.6	119	166	278	170	64.9	90.6	123	186	124
12365800	64.7	99.2	133	338	173	34.6	51.9	69.8	114	70.5	27.5	36.9	46.4	72.7	47.6
12366000	100	160	230	491	270	39.5	74.2	105	184	107	28.4	62.8	82.3	133	83.7
12369200	103	185	263	523	296	53.0	74.7	98.8	182	109	38.8	56.5	69.2	124	78.7
12370000	734	1090	1470	2890	1660	416	545	663	1060	705	353	435	513	769	550
12376000	31.5	73.8	103	243	122	22.7	31.5	36.3	66.0	41.2	19.2	23.2	27.6	44.3	31.6
12378000	78.6	148	201	344	204	34.0	69.1	83.4	155	87.7	27.0	43.0	52.9	85.1	55.3
12378500	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12379500	73.5	173	214	370	222	25.6	41.0	101	172	93.8	24.8	31.8	63.0	118	64.2
12381000	30.4	35.8	50.2	71.2	50.7	21.8	26.3	32.4	55.8	34.6	18.8	20.8	23.3	37.9	25.5
12381400	70.0	89.0	104	183	124	34.0	45.0	57.5	88.1	60.5	24.0	30.0	35.0	54.0	37.2
12381500	112	139	156	273	190	55.9	80.0	109	140	103	42.0	52.5	61.9	98.0	65.0
12382000	37.8	49.0	72.8	145	89.2	14.1	21.1	26.5	37.9	26.0	11.0	17.0	21.9	31.9	21.1
12382500	7.7	12.2	16.7	32.0	20.4	3.5	4.9	6.2	12.3	6.8	2.6	4.4	6.8	12.5	6.7
12383500	14.7	19.4	23.3	41.2	25.9	9.8	12.9	15.1	20.9	15.4	9.0	10.6	11.9	15.7	11.7
12385000	11.0	15.8	22.3	47.5	26.9	5.9	7.8	9.8	14.5	9.8	4.8	6.0	7.6	10.4	7.6
12388500	12.1	17.2	21.2	48.9	29.3	5.5	9.0	11.3	16.2	10.8	4.6	6.1	8.2	13.6	8.4
12389500	246	337	405	696	443	171	225	256	338	255	147	187	210	269	208
12390700	100	126	149	276	171	69.1	80.3	88.1	112	88.4	52.0	61.7	67.6	78.7	66.0
12391550	145	244	323	740	396	84.7	120	149	237	155	78.8	101	116	160	118

Table 12. Basin and climatic characteristics and channel widths for selected streamflow-gaging stations

[Basin/climatic characteristic: *A*, drainage area, in square miles; *E6*, percentage of basin above 6,000 feet elevation, plus 1; *PE*, basin perimeter, in miles; *BSL*, basin slope, dimensionless; *L*, main-channel length, in miles; *P*, mean annual precipitation, in inches; *E*, mean basin elevation, in thousands of feet; *BR*, maximum basin relief, in thousands of feet. Channel width: W_{AC}, active-channel width, in feet; W_{BF}, bankfull width, in feet; --, no data]

Gaging station	*A*	*E6*	*PE*	*BSL*	*L*	*P*	*E*	*BR*	W_{AC}	W_{BF}
06024500	71.4	101	44.6	0.25	19.3	30	7.11	2.04	39	48
06029000	30.8	98.2	29.9	.22	8.80	21	7.33	2.91	--	--
06062500	32.7	87.2	27.9	.30	8.80	24	6.58	3.41	16	25
06073000	123	77.0	66.3	.41	21.8	37	6.23	4.66	54	83
06078500	258	62.0	84.5	.35	27.4	42	6.15	4.62	--	--
12300500	110	2.00	47.1	.19	18.7	28	4.55	3.27	22	29
12301300	440	6.00	126	.24	40.2	32	4.17	4.99	48	58
12301999	216	1.00	96.2	.23	29.4	27	4.10	4.03	40	47
12302055	838	1.00	169	.24	66.4	32	4.10	5.13	111	130
12302500	23.6	32.0	25.0	.56	9.40	67	5.26	5.97	--	--
12303100	11.1	44.9	16.8	.52	5.90	67	5.24	4.83	17	24
12324100	39.5	94.0	33.9	.37	12.7	35	7.60	4.31	22	28
12330000	71.3	84.0	41.1	.33	13.5	31	6.98	4.77	28	32
12332000	123	90.0	61.3	.29	20.2	35	7.18	5.08	56	71
12335000	481	48.0	114	.34	47.7	15	5.89	5.10	100	120
12338690	140	55.0	72.3	.36	26.0	35	5.91	4.05	52	68
12339450	345	27.0	112	.25	35.7	37	5.28	5.27	90	110
12343400	381	62.0	116	.40	35.3	32	6.45	5.10	70	90
12346500	87.8	83.0	52.4	.43	12.9	36	6.80	4.61	34	44
12347500	26.4	68.0	30.5	.62	12.3	64	6.73	4.96	30	38
12350000	26.8	69.0	27.2	.54	11.8	63	6.43	5.01	41	47
12350500	28.9	66.0	25.6	.62	10.5	64	6.35	5.69	38	46
12351000	73.2	71.0	44.8	.37	16.7	32	6.57	4.41	20	28
12352000	250	34.3	93.6	.42	30.9	52	5.43	5.82	51	60
12353280	170	25.0	66.6	.35	25.1	38	4.92	4.96	48	60
12354000	303	2.00	99.3	.43	37.1	52	4.52	4.67	130	136
12356500	20.7	33.2	23.8	.27	8.10	47	5.77	4.13	25	36
12357000	510	47.0	126	.44	60.0	52	5.90	4.83	172	192
12359500	184	56.5	75.3	.40	29.8	56	6.00	5.17	65	105
12360000	47	58.0	36.3	.48	15.4	53	5.30	4.16	41	59
12360500	22.4	31.4	25.2	.49	8.90	56	5.49	4.16	32	44
12361000	71.3	39.0	50.3	.47	13.0	35	5.51	4.03	63	78
12361500	27.0	43.0	24.8	.50	9.00	67	5.43	3.96	40	60
12364000	183	7.00	71.3	.24	34.9	28	4.91	2.95	47	67
12365000	524	4.00	158	.25	50.5	31	4.32	4.39	70	85
12365800	78.0	30.0	54.8	.35	26.3	51	5.20	4.44	44	56
12366000	170	12.0	97.4	.23	36.9	37	4.17	4.48	64	82
12369200	73.3	40.0	49.8	.33	19.0	54	5.83	5.36	72	84
12370000	671	27.0	172	.33	84.5	23	5.02	6.33	165	185
12376000	50.6	17.7	37.9	.38	16.9	45	4.85	5.60	30	42
12378000	74.8	31.0	40.9	.33	14.8	48	4.84	6.63	--	--
12378500	22.6	15.4	26.8	.64	12.7	66	6.12	6.76	35	40
12379500	67.1	22.0	39.0	.40	17.3	45	4.75	7.09	28	33
12381000	15.9	5.74	21.4	.46	10.9	38	5.65	3.69	22	25
12381400	58.3	32.5	42.3	.35	18.6	39	6.06	4.23	32	36
12381500	74.2	37.2	49.4	.38	18.7	39	5.97	4.26	35	42
12382000	20.0	14.3	23.1	.41	9.10	64	6.15	4.08	32	38
12382500	3.59	3.76	11.6	.48	5.46	69	6.63	4.88	17	23
12383500	6.90	5.57	12.8	.55	5.92	40	6.32	4.29	12	16
12385000	6.51	5.44	11.4	.58	5.27	40	6.41	4.66	18	22
12388500	26.3	37.0	21.8	.29	9.35	33	5.56	4.21	--	--
12389500	642	6.00	145	.36	48.7	41	4.71	5.03	95	--
12390700	182	4.00	72.2	.47	21.5	54	4.41	4.39	44	67
12391550	139	10.0	58.3	.51	26.4	65	4.47	6.53	64	70

Table 13. Weights and standard errors for various combinations of methods of estimation

[*Q.xx*, daily mean discharge exceeded *xx* percent of time during specified month, in cubic feet per second; *QM*, mean monthly discharge, in cubic feet per second; log, logarithm, base 10; pct, percent]

Combinations of methods of estimation	Weights for specified month and monthly flow characteristic				
	Q.90	Q.70	Q.50	Q.10	QM
	OCTOBER				
Basin-characteristics method	0.197	0.203	0.219	0.153	0.170
Channel-width method	.255	.159	.121	.233	.114
Concurrent-measurement method	.548	.638	.660	.614	.716
Weighted standard error (log)	.153	.094	.076	.087	.088
Weighted standard error (pct)	36	22	18	20	21
Basin-characteristics method	.719	.646	.547	.305	.397
Channel-width method	.281	.354	.453	.695	.603
Weighted standard error (log)	.302	.246	.217	.212	.183
Weighted standard error (pct)	79	61	53	52	44
Concurrent-measurement method	.551	.659	.689	.667	.762
Basin-characteristics method	.449	.341	.311	.333	.238
Weighted standard error (log)	.166	.101	.081	.096	.090
Weighted standard error (pct)	40	24	19	22	21
Concurrent-measurement method	.588	.690	.712	.628	.757
Channel-width method	.412	.310	.288	.372	.243
Weighted standard error (log)	.159	.104	.090	.092	.094
Weighted standard error (pct)	38	24	21	21	22
	NOVEMBER				
Basin-characteristics method	0.181	0.235	0.209	0.176	0.190
Channel-width method	.203	.063	.015	.202	.023
Concurrent-measurement method	.616	.702	.776	.622	.787
Weighted standard error (log)	.129	.073	.063	.075	.071
Weighted standard error (pct)	30	17	15	17	16
Basin-characteristics method	.641	.591	.500	.380	.460
Channel-width method	.359	.409	.500	.620	.540
Weighted standard error (log)	.255	.230	.209	.190	.191
Weighted standard error (pct)	64	57	51	46	46
Concurrent-measurement method	.640	.718	.782	.696	.798
Basin-characteristics method	.360	.282	.218	.304	.202
Weighted standard error (log)	.138	.075	.063	.085	.071
Weighted standard error (pct)	33	17	15	20	16
Concurrent-measurement method	.667	.763	.835	.661	.852
Channel-width method	.333	.237	.165	.339	.148
Weighted standard error (log)	.135	.090	.078	.085	.083
Weighted standard error (pct)	32	21	18	20	19
	DECEMBER				
Basin-characteristics method	0.158	0.163	0.168	0.182	0.197
Channel-width method	.167	.026	.000	.161	.037
Concurrent-measurement method	.675	.811	.832	.657	.766
Weighted standard error (log)	.130	.075	.065	.089	.091
Weighted standard error (pct)	31	17	15	21	21
Basin-characteristics method	.683	.586	.542	.430	.500
Channel-width method	.317	.414	.458	.570	.500
Weighted standard error (log)	.258	.218	.213	.201	.204
Weighted standard error (pct)	65	54	52	49	50
Concurrent-measurement method	.697	.820	.832	.725	.783
Basin-characteristics method	.303	.180	.168	.275	.217
Weighted standard error (log)	.136	.075	.065	.096	.091
Weighted standard error (pct)	32	17	15	22	21
Concurrent-measurement method	.728	.872	.900	.712	.839
Channel-width method	.272	.128	.100	.288	.161
Weighted standard error (log)	.134	.082	.076	.099	.102
Weighted standard error (pct)	32	19	18	23	24
	JANUARY				
Basin-characteristics method	0.159	0.091	0.099	0.189	0.115
Channel-width method	.139	.060	.042	.086	.009
Concurrent-measurement method	.701	.849	.859	.726	.875
Weighted standard error (log)	.124	.083	.084	.096	.106
Weighted standard error (pct)	29	19	20	22	25
Basin-characteristics method	.583	.583	.500	.428	.500
Channel-width method	.417	.417	.500	.572	.500
Weighted standard error (log)	.267	.217	.207	.201	.203
Weighted standard error (pct)	68	53	51	49	49
Concurrent-measurement method	.733	.872	.879	.769	.881
Basin-characteristics method	.267	.128	.121	.231	.119
Weighted standard error (log)	.129	.084	.085	.098	.106
Weighted standard error (pct)	30	19	20	23	25
Concurrent-measurement method	.751	.891	.903	.788	.940
Channel-width method	.249	.109	.097	.212	.060
Weighted standard error (log)	.130	.085	.087	.107	.109
Weighted standard error (pct)	31	20	20	25	26

Table 13. Weights and standard errors for various combinations of methods of estimation—Continued

Combinations of methods of estimation	Weights for specified month and monthly flow characteristic Q.90	Q.70	Q.50	Q.10	QM
	FEBRUARY				
Basin-characteristics method	0.196	0.114	0.101	0.276	0.183
Channel-width method	.036	.058	.085	.024	.041
Concurrent-measurement method	.768	.828	.814	.700	.776
Weighted standard error (log)	.100	.080	.080	.100	.095
Weighted standard error (pct)	23	19	19	23	22
Basin-characteristics method	.669	.624	.611	.500	.610
Channel-width method	.331	.376	.389	.500	.390
Weighted standard error (log)	.236	.211	.197	.224	.207
Weighted standard error (pct)	58	52	48	55	50
Concurrent-measurement method	.778	.848	.849	.710	.793
Basin-characteristics method	.222	.152	.151	.290	.207
Weighted standard error (log)	.101	.081	.082	.100	.096
Weighted standard error (pct)	23	19	19	23	22
Concurrent-measurement method	.844	.881	.869	.769	.864
Channel-width method	.156	.119	.131	.231	.136
Weighted standard error (log)	.109	.084	.083	.122	.103
Weighted standard error (pct)	26	19	19	29	24
	MARCH				
Basin-characteristics method	0.186	0.138	0.171	0.304	0.208
Channel-width method	.000	.086	.069	.000	.025
Concurrent-measurement method	.814	.776	.760	.696	.767
Weighted standard error (log)	.098	.084	.093	.120	.103
Weighted standard error (pct)	23	19	22	28	24
Basin-characteristics method	.616	.612	.610	.538	.608
Channel-width method	.384	.388	.390	.462	.392
Weighted standard error (log)	.219	.207	.207	.240	.216
Weighted standard error (pct)	54	51	50	60	53
Concurrent-measurement method	.814	.807	.787	.696	.778
Basin-characteristics method	.186	.193	.213	.304	.222
Weighted standard error (log)	.098	.086	.094	.120	.103
Weighted standard error (pct)	23	20	22	28	24
Concurrent-measurement method	.909	.841	.841	.773	.862
Channel-width method	.091	.159	.159	.227	.138
Weighted standard error (log)	.107	.089	.100	.144	.113
Weighted standard error (pct)	25	21	23	34	27
	APRIL				
Basin-characteristics method	0.222	0.315	0.271	0.256	0.286
Channel-width method	.132	.147	.131	.131	.159
Concurrent-measurement method	.645	.538	.597	.613	.555
Weighted standard error (log)	.104	.095	.097	.087	.105
Weighted standard error (pct)	24	22	23	20	25
Basin-characteristics method	.593	.571	.549	.474	.500
Channel-width method	.407	.429	.451	.526	.500
Weighted standard error (log)	.200	.174	.192	.222	.191
Weighted standard error (pct)	49	42	46	55	46
Concurrent-measurement method	.698	.613	.666	.671	.638
Basin-characteristics method	.302	.387	.334	.329	.362
Weighted standard error (log)	.109	.103	.103	.095	.114
Weighted standard error (pct)	26	24	24	22	27
Concurrent-measurement method	.750	.692	.729	.691	.671
Channel-width method	.250	.308	.271	.309	.329
Weighted standard error (log)	.117	.128	.123	.118	.135
Weighted standard error (pct)	27	30	29	28	32
	MAY				
Basin-characteristics method	0.257	0.220	0.207	0.209	0.194
Channel-width method	.235	.290	.320	.346	.316
Concurrent-measurement method	.508	.490	.474	.445	.490
Weighted standard error (log)	.097	.086	.089	.101	.090
Weighted standard error (pct)	23	20	21	24	21
Basin-characteristics method	.440	.395	.390	.406	.413
Channel-width method	.560	.605	.610	.594	.587
Weighted standard error (log)	.214	.174	.167	.149	.155
Weighted standard error (pct)	52	42	40	35	37
Concurrent-measurement method	.582	.614	.606	.596	.629
Basin-characteristics method	.418	.386	.394	.404	.371
Weighted standard error (log)	.115	.113	.118	.126	.116
Weighted standard error (pct)	27	26	28	30	27
Concurrent-measurement method	.561	.555	.538	.524	.565
Channel-width method	.439	.445	.462	.476	.435
Weighted standard error (log)	.122	.106	.105	.112	.102
Weighted standard error (pct)	29	25	24	26	24

Table 13. Weights and standard errors for various combinations of methods of estimation—Continued

Combinations of methods of estimation	Weights for specified month and monthly flow characteristic				
	Q.90	Q.70	Q.50	Q.10	QM
JUNE					
Basin-characteristics method	0.274	0.203	0.179	0.241	0.192
Channel-width method	.260	.315	.305	.402	.331
Concurrent-measurement method	.465	.482	.516	.357	.478
Weighted standard error (log)	.119	.091	.080	.101	.081
Weighted standard error (pct)	28	21	19	24	19
Basin-characteristics method	.601	.579	.572	.466	.535
Channel-width method	.399	.421	.428	.534	.465
Weighted standard error (log)	.233	.175	.161	.133	.145
Weighted standard error (pct)	58	42	38	31	34
Concurrent-measurement method	.487	.520	.569	.472	.551
Basin-characteristics method	.513	.480	.431	.528	.449
Weighted standard error (log)	.132	.116	.107	.133	.110
Weighted standard error (pct)	31	27	25	31	26
Concurrent-measurement method	.513	.548	.588	.455	.558
Channel-width method	.487	.452	.412	.545	.442
Weighted standard error (log)	.132	.100	.088	.111	.089
Weighted standard error (pct)	31	23	20	26	21
JULY					
Basin-characteristics method	0.294	0.196	0.116	0.006	0.088
Channel-width method	.210	.236	.304	.496	.367
Concurrent-measurement method	.496	.568	.580	.498	.545
Weighted standard error (log)	.158	.115	.101	.093	.111
Weighted standard error (pct)	38	27	24	22	26
Basin-characteristics method	.571	.611	.500	.456	.500
Channel-width method	.429	.389	.500	.544	.500
Weighted standard error (log)	.317	.255	.224	.174	.192
Weighted standard error (pct)	84	64	55	42	46
Concurrent-measurement method	.510	.587	.622	.523	.594
Basin-characteristics method	.490	.413	.378	.477	.406
Weighted standard error (log)	.164	.127	.121	.141	.135
Weighted standard error (pct)	39	30	28	33	32
Concurrent-measurement method	.521	.606	.608	.500	.573
Channel-width method	.479	.394	.392	.500	.427
Weighted standard error (log)	.170	.122	.104	.093	.112
Weighted standard error (pct)	41	29	24	22	26
AUGUST					
Basin-characteristics method	0.137	0.079	0.020	0.000	0.000
Channel-width method	.342	.344	.360	.358	.364
Concurrent-measurement method	.520	.577	.621	.642	.636
Weighted standard error (log)	.180	.140	.119	.081	.113
Weighted standard error (pct)	43	33	28	19	26
Basin-characteristics method	.411	.500	.635	.500	.567
Channel-width method	.589	.500	.365	.500	.433
Weighted standard error (log)	.360	.323	.300	.238	.265
Weighted standard error (pct)	99	86	78	59	67
Concurrent-measurement method	.539	.593	.621	.688	.651
Basin-characteristics method	.461	.407	.379	.312	.349
Weighted standard error (log)	.193	.158	.142	.122	.138
Weighted standard error (pct)	47	38	34	29	33
Concurrent-measurement method	.529	.586	.625	.642	.636
Channel-width method	.471	.414	.375	.358	.364
Weighted standard error (log)	.182	.141	.119	.081	.113
Weighted standard error (pct)	44	33	28	19	26
SEPTEMBER					
Basin-characteristics method	0.149	0.053	0.040	0.045	0.049
Channel-width method	.303	.322	.314	.301	.259
Concurrent-measurement method	.548	.625	.646	.654	.693
Weighted standard error (log)	.169	.120	.102	.083	.091
Weighted standard error (pct)	40	28	24	19	21
Basin-characteristics method	.663	.571	.633	.561	.623
Channel-width method	.337	.429	.367	.439	.377
Weighted standard error (log)	.363	.317	.289	.213	.238
Weighted standard error (pct)	100	84	75	52	59
Concurrent-measurement method	.550	.637	.653	.681	.711
Basin-characteristics method	.450	.363	.347	.319	.289
Weighted standard error (log)	.181	.139	.122	.101	.105
Weighted standard error (pct)	44	33	29	24	25
Concurrent-measurement method	.565	.633	.654	.666	.706
Channel-width method	.435	.367	.346	.334	.294
Weighted standard error (log)	.172	.120	.102	.083	.092
Weighted standard error (pct)	41	28	24	19	21

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